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# PAKISTAN AT THE FLOOD TIPPING POINT

## Systemic Risk, Climate Breakdown and the Pathway to Resilience

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# WHY THIS REPORT MATTERS

Pakistan ranks among the world's most climate-vulnerable countries, and this report argues that it may now have reached a dangerous tipping point.

This multi-authored, multidisciplinary report shows that without urgent, strategic, and effective action, Pakistan risks crossing a threshold beyond which increasingly erratic and compounding water-related disasters, heatwaves, droughts, accelerated glacier melt, and wider ecological breakdown will cause deeper and more sustained national harm.

These risks are no longer abstract. Recent catastrophic floods have already shown the scale of devastation and the science, data, and analysis brought together in this report make clear that the danger is real and escalating. The implications go far beyond environmental damage. Pakistan now faces severe and interconnected risks to development, food and water security, public health, economic stability, and national security.

Extreme weather events do not only destroy homes, crops, roads, and public infrastructure. They contaminate water, spread pollutants through soils and food systems, damage ecosystems, harm human health, reduce productivity, and weaken economic resilience. In a country already facing rapid population growth, constrained resources, fiscal pressure, and rising geopolitical instability, shocks of this scale cannot be absorbed indefinitely.

This report shows that Pakistan is inadequately positioned to confront these risks. The gaps are structural and severe. Financially, spending on adaptation and resilience has remained only a very small fraction of defence spending, despite cumulative economic losses from floods since 2010 being broadly similar in scale to defence spending. Institutionally, the report identifies a system that remains fragmented, reactive, and poorly aligned to the risks now unfolding: weak enforcement, floodplain encroachment, poor data-sharing, underinvestment in prevention, political distortion, and repeated failure to convert lessons including those identified in formal and internal assessments into reform.

This report brings together expert insight, systems analysis, hydrology, climate science, governance review, adaptation strategy, community resilience, and environmental risk to explain why Pakistan is so critically exposed and what must now be done to protect it in the short, medium, and long term. It considers each of these elements through a systems lens to show how they interact and reinforce one another. It is not intended to be an exhaustive treatment of every issue in isolation, but to bring the scientific, institutional, environmental, and strategic dimensions together in support of effective action.

The report also makes clear that even effective domestic action will not be enough on its own. Pakistan shares river systems, cryosphere influences, atmospheric systems, and ecological linkages with neighbouring countries. Transboundary cooperation is therefore essential. Without stronger coordination, data-sharing, and ecological cooperation across shared systems, even the best internal reforms will remain constrained. Protecting ecosystems the foundation of life, resilience, and economic stability requires cooperation both within Pakistan and beyond its borders.

This report concerns everyone, because everyone is a stakeholder: government, public institutions, businesses, economists, national strategists, international experts, development partners, multilateral bodies, researchers and the wider public. It shows at Pakistan needs more than minor adjustment; it needs a strategic reset, and that reset must be discussed, funded, and implemented at every level. Without an informed plan and urgent call to action, Pakistan risks losing control of its ability to protect its people, economy, and ecosystems from the worst impacts of climate change and disaster. That is not simply an environmental danger. It is a national emergency and a national security risk.

# EXECUTIVE SUMMARY

Pakistan's flood crisis is no longer a story of periodic natural disasters. It is the result of intensifying hydroclimatic extremes interacting with fragmented governance, high-risk development patterns, degraded ecosystems, repeated failures to convert lessons into reform, and a wider regional hydrological context in which upstream climate impacts and weak transboundary cooperation can amplify downstream risk in Pakistan.

The central finding of this report is that floods become disasters not simply because rainfall is extreme, but because risk is amplified across a system that is structurally exposed on multiple levels, institutionally disjointed, environmentally degraded,and exposed to interconnected and compounding risks.

The scale of the challenge is national in every sense: humanitarian, ecological, fiscal, and strategic. Between 2010 and 2025, cumulative flood losses are estimated at approximately US$80-85 billion. The 2022 floods alone caused around US$30 billion in damage and losses and generated US$16.3 billion in resilient reconstruction needs. The 2025 floods added a further major shock, with losses estimated at approximately PKR 822 billion (US$2.9 billion) and a projected reduction in GDP of 0.5–1.0%. These repeated shocks are not isolated events; they are systemic disruptions that undermine development, strain public finances, damage infrastructure, destabilise food systems, and erode long-term national resilience.

Crucially, these risks do not operate independently. They interact to produce compound and cascading impacts, where climate hazards, environmental degradation, governance failures, transboundary information deficits, and socioeconomic vulnerability reinforce one another. This report is therefore structured to move from diagnosis to solution, examining how these interacting forces shape outcomes and how they can be addressed through integrated reform.

The report begins by framing Pakistan's flood crisis as a systems problem (Chapter I). It shows that outcomes are shaped by the interaction of five interdependent subsystems: hydrology and environment, institutions and governance, socioeconomic and land-use dynamics, information and decision-making, and community resilience. Flood losses, urban inundation, infrastructure stress, and weak recovery are not isolated failures but recurring outcomes of reinforcing feedback loops. This systems perspective underpins the entire report and provides the analytical framework through which subsequent chapters interpret risk and identify leverage points for change.

Building on this foundation, Chapter II examines why floods become disasters by tracing both physical and human drivers. Pakistan experiences multiple flood typesriverine, flash, urban, glacial lake outburst floods, cloudburst-induced floods, and coastal floodingall of which are intensifying as climate change alters rainfall patterns, moisture pathways, monsoon dynamics, and cryosphere behaviour. Large-scale climate drivers such as La Niña, the Indian Ocean Dipole, and land–sea thermal contrasts interact with local anthropogenic pressures including deforestation, biomass burning, urbanisation, and the expansion of irrigated agriculture. These intensifying hazard dynamics interact directly with the systemic vulnerabilities identified in Chapter I, transforming natural events into large-scale disasters.

Chapter III then examines the institutional dimension of this system. It shows that Pakistan's flood governance architecture is fragmented across federal, provincial, and local levels, with overlapping mandates, weak accountability, and inconsistent implementation. Critical functions including water management, infrastructure development, disaster response, and climate policy operate in silos that do not consistently align. This institutional fragmentation is a key mechanism through which the systemic risks identified in earlier chapters translate into real world disaster outcomes. The issue is not a lack of institutions, but a lack of coherence, coordination, and sustained implementation.

Chapter IV places these dynamics in historical, political, and regional context, demonstrating how Pakistan has become locked into a recurring cycle of loss and incomplete reform. Across major flood events 2010, 2022, and 2025 failures are repeatedly identified, yet structural change remains partial and uneven. Attribution science shows that climate change is already increasing the intensity and likelihood of extreme events, further raising the stakes. The chapter also highlights the transboundary dimension of flood risk: Pakistan and India are ecologically linked through shared river basins, the Hindu Kush–Karakoram–Himalaya cryosphere, deserts, and monsoon systems, yet they lack the scientific collaboration, real-time data exchange, and early warning cooperation needed to reduce downstream damages. The report argues that regional cooperation failure is not a secondary issue but a measurable amplifier of Pakistani flood losses.

The report then shifts toward solutions. Chapter V advances an adaptation-centred framework, arguing that Pakistan must move beyond the historic paradigm of attempting to control floods through rigid infrastructure alone. Instead, it calls for a more integrated approach that combines improved early warning systems, climate-informed planning, selective structural protection, and ecosystem-based measures such as floodplain reconnection and watershed restoration. This represents a shift away from the reactive patterns described in earlier chapters toward a more preventive and adaptive model of risk management.

Chapter VI builds on this by demonstrating the central role of community-based disaster risk management. In many high-risk areas, communities are the first responders, yet local preparedness remains uneven and under-resourced. In the context of institutional limitations highlighted in Chapter III, community-based approaches are not supplementary; they are essential components of national resilience. Strengthening local capacity through training, early warning access, local planning, and integration with formal systems can significantly reduce disaster impacts and support more effective recovery.

Chapter VII adds a critical but often overlooked dimension by showing that floods are also pollution-redistribution events. Environmental contaminants including black carbon, particulate matter, chemical pollutants, and nano/microplastics are mobilised, transported, and concentrated during flood events, amplifying risks to ecosystems, agriculture, water systems, and human health. Black carbon contributes to cryosphere destabilisation, while particulate pollution can influence atmospheric processes and rainfall patterns. Emerging evidence on nano/microplastics raises particular concern because of their capacity to penetrate biological barriers, transport adsorbed toxins, and accumulate within human tissues. The chapter demonstrates that pollution is not a separate environmental issue, but a cross-cutting risk amplifier that interacts with hydrological processes, climate dynamics, and human exposure pathways. It therefore reinforces the need to integrate pollution control, clean air policy, and environmental health into flood-risk governance.

Taken together, the chapters reveal a consistent and urgent conclusion: Pakistan's flood crisis is driven by compound and cascading risks within a fragmented system. Climate change is intensifying hazards, but it is the interaction with environmental degradation, institutional misalignment, transboundary cooperation deficits, and socioeconomic exposure that transforms these hazards into disasters. Addressing any one of these elements in isolation will be insufficient. Effective risk reduction requires integrated action across all parts of the system.

The report therefore calls for a fundamental shift from reactive disaster response to integrated flood-risk governance. This includes mainstreaming climate-risk assessment into infrastructure planning, enforcing floodplain management, strengthening institutional coordination, modernising early warning systems, prioritising maintenance, scaling community resilience, restoring ecosystems, integrating pollution and environmental health into national resilience strategies, and strengthening regional technical cooperation on data-sharing, forecasting, and shared hydrological risks. Flood risk must be treated not as a sectoral issue, but as a core national priority linked to economic stability, public health, environmental sustainability, and national security.

Pakistan does not lack knowledge. The science is clear, the risks are understood, and this report adds further insight into their interconnected and amplified nature. Lessons have been repeatedly identified; what is now required is decisive, coordinated action at scale. Without it, the country will remain locked in a cycle of escalating loss. With it, Pakistan has the opportunity to move toward a more resilient, adaptive, and secure future. The window for that transition is narrowing

# INTRODUCTION

## Background, Economic Context and Rationale

From the 2010 Indus Basin floods to the most recent major flood event in 2025, Pakistan has faced several major flood disasters that have claimed thousands of lives and left entire landscapes devastated. Across just these fifteen years, total flood-related loss and damage is estimated at approximately US$80–85 billion. To put that in perspective, Pakistan's total GDP in 2025 was around US$410 billion, meaning that cumulative flood losses over this period amount to roughly 20% of one year's GDP. This is an extraordinary economic burden for any country and demonstrates how deeply climate-linked disasters are already affecting Pakistan's development trajectory.

The comparison with national spending priorities is equally striking. Pakistan's total federal budget for FY2025–26 was PKR 17.57 trillion (about US$62 billion), of which the federal defence budget accounted for PKR 2.55 trillion (about US$9 billion), or 14.5% of the total federal budget. Defence spending was equivalent to approximately 1.9% of GDP. Yet climate resilience, disaster management, and flood protection receive only a small fraction of that level of support, despite the fact that the danger from recurrent flood disasters is far more certain and immediate than the outbreak of war. Over the period from 2010 to 2025, Pakistan has lost almost the same broad order of magnitude to floods as it has spent on defence, while spending on disaster prevention and climate resilience has remained only a very small proportion of defence expenditure.

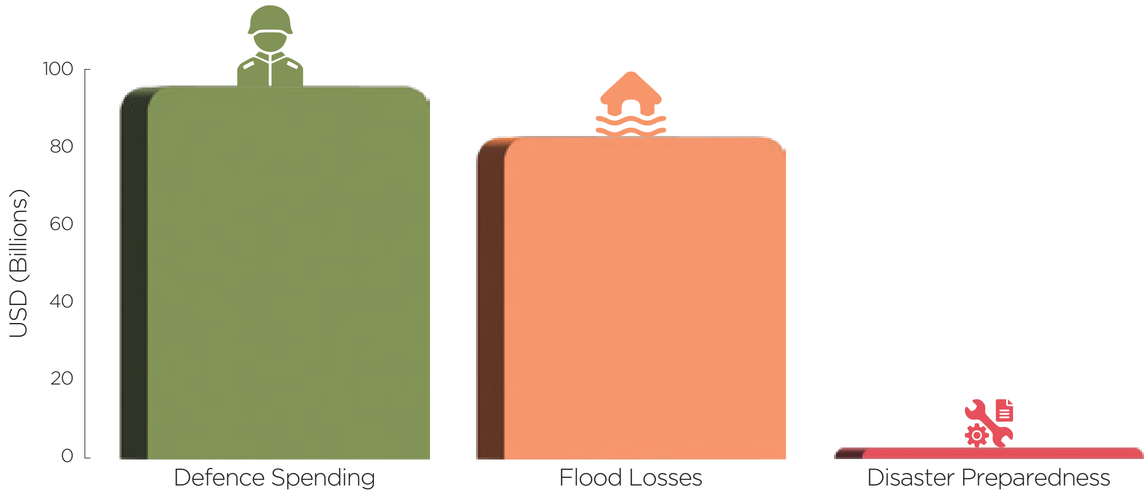
This comparison is not intended to diminish the importance of defence. Rather, it highlights a strategic imbalance. Flood management, watershed restoration, resilient infrastructure, and early warning systems are not peripheral environmental concerns; they are core national security priorities. If Pakistan continues to underinvest in prevention while repeatedly absorbing catastrophic losses, it will remain trapped in a cycle of destruction, reconstruction, and declining resilience.

This pattern is reflected in the available financial data. Estimated total defence spending between 2010 and 2025 stood at approximately PKR 20–22 trillion (around US$90–100 billion), while total flood losses over the same period reached roughly US$80–85 billion, bringing them close to parity in strategic scale. By contrast, total spending on disaster preparedness and climate adaptation over the same period is estimated at only PKR 500–700 billion (about US$2–3 billion), or around 3% of defence spending. Average annual flood protection spending has been in the range of PKR 25–40 billion, largely through provincial irrigation and flood protection programmes. Federal disaster management allocations have remained minimal, with the National Disaster Management Authority operating on roughly PKR 2–5 billion annually, while provincial disaster management budgets have generally remained in the range of PKR 10–15 billion annually, limiting both preparedness and capacity-building.

| Indicator | Estimated Amount | Share / Comparison | Key Notes |
|---|---|---|---|
| Total Defence Spending (2010 – 2025) | PKR 20–22 trillion (≈ $90–100 billion) | Baseline reference | Defence budget increased from PKR 442 billion in 2010 to about PKR 2.55 trillion by 2025. |
| Total Flood Losses (2010–2025) | ≈ $80–85 billion | Nearly equal to total defence spending | Includes major flood disasters in 2010, 2011, 2012–2015, 2022, and 2025. |
| Disaster Preparedness & Climate Adaptation Spending | PKR 500–700 billion (≈ $2–3 billion) | ~3% of defence spending | Includes spending on flood protection, climate resilience, and disaster management institutions. |
| Average Annual Flood Protection Spending | PKR 25–40 billion | Minimal national allocation | Mainly through provincial irrigation and flood protection programs. |
| Federal Disaster Management Budget | PKR 2–5 billion annually | PKR 2–5 billion annually | Managed by the National Disaster Management Authority. |
| Provincial Disaster Management Budgets | PKR 10–15 billion annually | Limited capacity building | Implemented through Provincial Disaster Management Authorities. |

The wider economic burden is also severe in event-specific terms. The 2022 floods caused around US$30 billion in damage and losses and generated US$16.3 billion in resilient reconstruction needs under the Post-Disaster Needs Assessment. The 2025 floods alone caused losses estimated at Rs 822 billion (about US$2.9 billion) and were expected to reduce GDP by 0.5–1.0%. Seen in this light, flooding in Pakistan is not a marginal environmental issue. It is a recurring macroeconomic shock. Public resources are repeatedly diverted into relief, repair, and reconstruction. Productive assets are destroyed. Agriculture and transport systems are disrupted. Housing losses deepen social vulnerability. And because rebuilding often occurs within or near the same exposure zones, the country too often restores risk rather than reducing it.

## Pakistan: Defence spending vs Flood Losses vs Preparedess (2010- 2025)




This report has been prepared because Pakistan can no longer afford to treat floods as isolated emergencies or unavoidable acts of nature. It is an evidence-based report that examines the facts and the structural reasons behind Pakistan's recurrent flood crises, which are causing billions of dollars in damage to the economy as well as immense human suffering. It asks not only why these disasters keep happening, but how such astronomical losses can be prevented. At its core, the report argues that adaptation to climate change is not optional; it is essential if Pakistan is to reduce risk and vulnerability across a widening spectrum of natural hazards.

The broader framing is increasingly being recognised internationally. Governments are now seriously advancing assessments of biodiversity loss, ecosystem degradation, food insecurity, water disruption, health impacts, and climate-linked instability through a national-security lens, reflecting the reality that environmental breakdown can destabilise economies, supply chains, and social order. Recent international scientific and policy commentary has reinforced the same point from a water-security perspective: climate change and geopolitics are jointly threatening water systems, and the risk of disaster is real but not inevitable where institutions, cooperation, and long-term planning are strengthened. Pakistan should view recurrent extreme weather and ecosystem degradation with the same seriousness: not as isolated environmental concerns, but as systemic threats requiring proactive resilience planning.

The report begins from the premise that Pakistan's flood disasters are not inevitable. The country's exposure is shaped by a combination of intensifying climate hazards and human-made risk amplifiers. Climate change is increasing rainfall intensity, altering monsoon behaviour, and accelerating cryosphere change. At the same time, floodplain encroachment, rigid river engineering, degraded catchments, weak drainage, fragmented institutions, uneven enforcement, and underpowered local preparedness all magnify the impact of flood events.

That is why this report was assembled. Its purpose is not simply to document flood damage or repeat familiar warnings. It is to examine why the existing system remains fragmented and reactive, and to identify a more coherent pathway forward. The chapters that follow bring together systems analysis, hydrology, climate science, institutional review, adaptation strategy, community resilience, and environmental risk. Together they argue that Pakistan's flood challenge cannot be solved through isolated technical interventions or post-disaster response alone. It requires a proactive, systems-based approach that learns from past disasters, applies the best available global and emerging science, and builds stronger protective frameworks for the future.

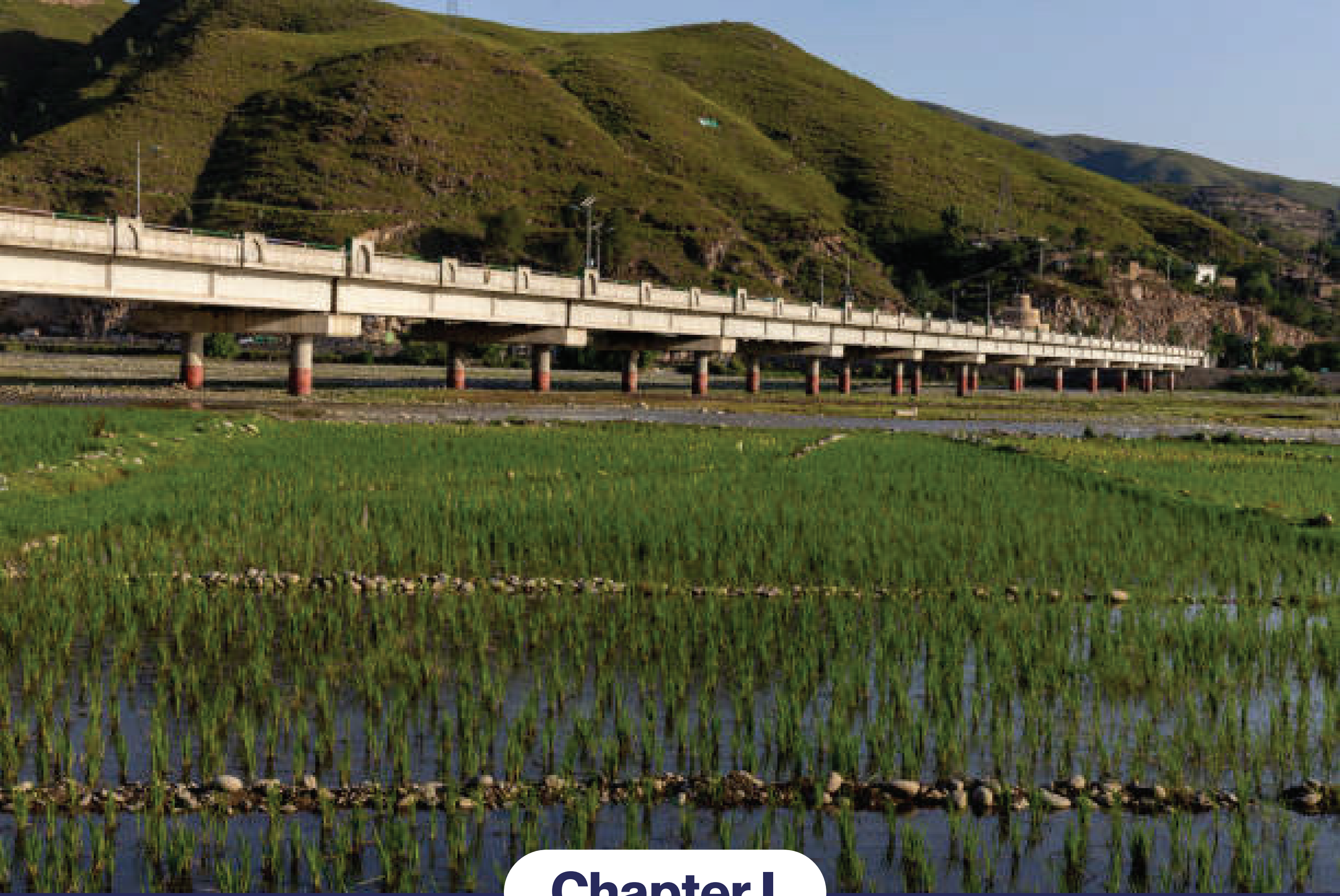
A final principle underpins the report. Ecosystems are not secondary to resilience; they are part of its foundation. Rivers, wetlands, forests, upland catchments, floodplains, and coastal systems all help regulate water, reduce hazard, sustain livelihoods,and support long-term national survival. Where they are degraded, risk intensifies. Where they are protected and restored, resilience grows.

This report will therefore play a critical role in shaping discourse on why flood management is now central to Pakistan's national security. It is a call to decision-makers to prioritise much stronger disaster management, with the urgency, seriousness, and coordination normally reserved for national emergencies, and to reduce risk through building resilience before the next crisis strikes. The practical question running through the report is clear: how can Pakistan move from repeated disaster to more intelligent flood-risk governance? The answer it offers is not a single solution, but a more integrated one that links science, policy, planning, institutions, ecosystems, and communities in a more durable framework for resilience.

## The Cycle of Recurring Flood Loss and Systemic Failure


**Without systemic response, each flood reinforces the next**

Figure 1. Cycle of Recurring Flood Loss and Systemic Failure in Pakistan
This figure illustrates how flood risk is reinforced through interacting systemic pressures, where climate change, institutional fragmentation, and reactive responses combine to reproduce vulnerability and economic loss over time.



Chapter I

# FROM FRAGMENTATION TO INTEGRATION:

## The Systemic Nature of Pakistan's Water Challenges

Willem Van Deursen

# 1. Introduction: Why Integration Matters

Every time we study floods in Pakistan, we end up drawing similar conclusions: infrastructure capacity is overstretched, institutions are fragmented, maintenance is underfunded, and climate pressures are intensifying. And yet, after each major event—2010, 2011, 2022, 2025—the system returns to the same patterns of management, investment, and decision-making. This recurring familiarity is not a coincidence. It reflects the underlying structure of the water governance system itself.

The core challenge is that Pakistan's water sector is not a single system—it is many systems whose interactions determine outcomes. Flood management, irrigation planning, groundwater abstraction, drainage, urban expansion, fiscal priorities, early warning, and climate risk governance are treated as separate domains. But water does not respect these boundaries. When hydrology moves across landscapes, it moves across institutional mandates as well.

Recurring outcomes—chronic shortages, declining reliability, destructive floods, and infrastructure deterioration—are not failures of individual actors. They are emergent properties of how the system is structured. And unless we understand the system as a whole, we cannot change the pattern.
This section serves one purpose: to bring together the insights from the full report into a single, coherent systems understanding of Pakistan's water challenges. It does not add new data. Instead, it interprets what the different sections/chapters collectively show and translates that into a systemic narrative.

## Punjab Under Flood 2025

In the summer of 2025, Pakistan once again faced the wrath of monsoon floods, with Punjab bearing the brunt. Images of submerged villages, stranded communities, and collapsing infrastructure dominated headlines, yet for many who experienced the floods firsthand, the chaos extended far beyond the water itself; for an extended time the streets remained blocked, basic services were disrupted, and the coordination between agencies seemed fractured. Compounding these challenges, the lack of accurate, open, digital, and verified data for key parameters—such as rainfall time series and river discharge measurements made any analysis had to rely largely on global open-source datasets. Comparing these datasets with locally monitored measurements proved difficult, further limiting the ability to understand the full scale of the floods and to learn lessons for future preparedness.

The 2025 floods were not merely a natural disaster; they were a stark demonstration of systemic failure. As prior investigations and reporting have shown, Pakistan's irrigation and water management systems—once hailed as engineering achievements—have struggled under mounting pressure. The failures were not just technical. Dams, embankments, and drainage networks were insufficiently maintained, poorly monitored, and, in some areas, outright mismanaged. When water spilled beyond the designed channels, the response systems struggled to adapt.

Equally revealing was the state of early warning and community preparedness. While meteorological services issued forecasts and flood alerts, their messages rarely translated into actionable local plans. Communities reported confusion over warnings, a lack of clear evacuation routes, and minimal guidance from local authorities. In many cases, warnings arrived too late, or their credibility had been eroded by years of false alarms. The resulting inaction was not a failure of people, but a failure of the system to enable them to act. [1 2]

Underlying these immediate failures were deeper structural issues. Land use planning and enforcement remain weak, allowing settlements and agricultural developments in high-risk flood zones. Governance coordination across federal, provincial, and local levels is fragmented, leaving critical gaps in decision-making and implementation. And, despite decades of data collection, essential hydrological, infrastructure, and social information is scattered, incomplete, or inaccessible to those who need it most.

The floods of 2025 again exposed the intertwined nature of Pakistan's water and governance crises. They were a reminder that natural hazards become disasters only when human systems fail to anticipate, absorb, and respond. This section, identifies critical points revealed by the disaster:

- Lack of governance coordination across agencies and administrative levels.
- Absence of a framework for local resilience, leaving communities unprepared to act effectively.
- Inadequate land use planning and enforcement, which placed lives and livelihoods directly in harm's way.
- Insufficient, fragmented data, limiting the ability to anticipate and respond to flood impacts.

These points provide the lens through which the following section will explore the broader system failures, the chaos they create, and the pathways toward building resilience in Pakistan's water management systems.

1 https://www.thefridaytimes.com/14-Oct-2025/sindh-s-2022-floods-reveal-failing-irrigation-systems-urgent-need-reform
2 https://www.thefridaytimes.com/30-Sep-2025/pakistan-s-flood-warnings-crying-wolf-building-real-resilience

# 2. The System as a Whole: A Simplified Framework

When I step back and look at Pakistan's water sector, I see five major subsystems that continuously interact:

1. Hydrological and Environmental System
2. Institutional and Governance System
3. Socioeconomic and Land-Use System
4. Information and Decision System
5. Community and System Resilience

These are not theoretical categories. They mirror how events like floods and droughts actually unfold.

## 2.1 Hydrological and Environmental System

This is the Indus Basin itself—rivers, tributaries, rainfall patterns, snowmelt, sediment dynamics, wetlands, aquifers, floodplains, and delta processes. The Indus is the only constant. Everything else changes around it: land use expands, infrastructure ages, groundwater declines, and climate patterns shift. Hydrology provides the boundary conditions for everything else that happens.

## 2.2 Institutional and Governance System

This includes federal ministries, provincial departments, autonomous agencies such as WAPDA and IRSA, disaster management authorities (NDMA/PDMA), municipal governments, utility agencies, and the judiciary. Their mandates often overlap. Their incentives rarely align. The system's architecture encourages short-term fixes, reactive investments, and a focus on capital rather than maintenance. Fragmentation is not a flaw—it is an inherited design.

## 2.3 Socioeconomic and Land-Use System

How people live in the basin matters as much as how water flows. Rural livelihoods depend on cropping choices that lock the system into high water demand. Urban expansion seals surfaces and blocks drainage. Poverty constrains the ability of communities to adapt or relocate. All of this increases exposure and vulnerability and shapes the politics of water decision-making.

## 2.4 Information and Decision System

This is the "mind" of the system: data, early warning, knowledge, accountability, media narratives, political interests, and administrative cycles. When information flows poorly, decisions follow the line of least resistance. The result is predictable: late warnings, reactive responses, and limited institutional learning. The system continuously reproduces its own blind spots.

## 2.5 Community and System Resilience

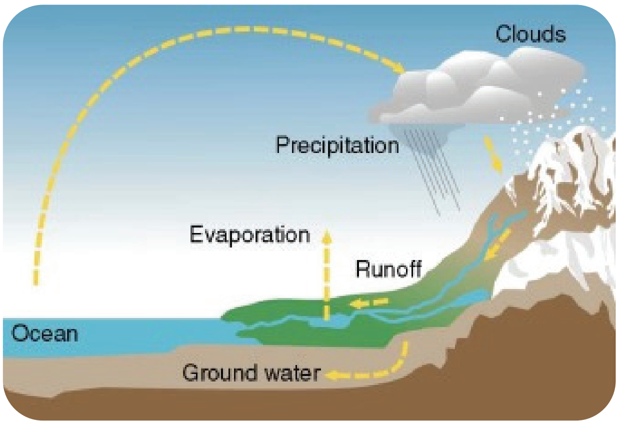
Community and system resilience is the capacity of people, institutions, and local environments to absorb shocks and adapt over time. It is the glue that connects the technical and the social; the space where hydrology meets lived reality. It includes:

- Local knowledge of floods, droughts, and river behavior.
- Social networks that determine who gets help, who evacuates, and who rebuilds.
- Informal institutions that fill gaps left by formal agencies.
- Community practices such as collective maintenance of drains, embankments, or irrigation channels.
- The ability to recover after disasters—not just physically, but economically and psychologically.

In Pakistan, resilience is unevenly distributed. Some communities have strong social cohesion and adaptive knowledge, while others face chronic vulnerability due to poverty, displacement, or exclusion. Meanwhile, the system as a whole—for example, the way budgets are allocated, how early warnings are issued, or how post-disaster reconstruction is organized—often undermines rather than reinforces resilience.

Community resilience determines how the flood actually becomes a disaster: the same hydrological event can be disruptive in one district and catastrophic in another.

As climate extremes intensify, this subsystem becomes the decisive one. Resilience is no longer an optional add-on—it is the operating condition under which Pakistan must now manage water.



## 3. How These Subsystems Interact

Major patterns in Pakistan's water sector—flood losses, groundwater depletion, urban inundation, or infrastructure stress—rarely originate from a single cause. They emerge from the interactions among the five subsystems, forming reinforcing loops and recurring dynamics that are often difficult to see from within any single agency or discipline. What appears as an isolated failure or crisis is often the predictable outcome of these interconnected forces.

**Pakistan has made substantial achievements:** decades of irrigation management, major dams, early warning systems, and extensive disaster response experience all demonstrate considerable capacity and ingenuity. Yet even well-intentioned actions can generate unintended consequences when multiple subsystems interact under conditions of complexity.

Viewed through a broader lens, these recurring patterns resemble the archetypes described by Peter Senge in The Fifth Discipline. Senge's work shows that complex systems—whether organizations or national water sectors—often fall into recognizable loops, such as over-reliance on short-term fixes, escalating pressures, or constraints on long-term growth. By framing Pakistan's water challenges in terms of these archetypical patterns, we can see not only why the system behaves as it does, but also where opportunities exist to intervene, adapt, and strengthen resilience.

In the following sections, I map four illustrative loops within Pakistan's water sector and show how they align with Senge's archetypes, highlighting both the challenges and potential leverage points for systemic improvement.

### 3.1. Shifting the burden: Maintenance Gaps → Infrastructure Stress → Emergency Response → New Projects

One of the most persistent interaction patterns in Pakistan's water sector revolves around the relationship between maintenance, hydrological pressure, and investment decisions. It is not driven by neglect or incompetence, but by a combination of institutional constraints, physical realities, and political incentives that repeatedly reinforce one another.

From an institutional perspective, maintenance is difficult to prioritize. Responsibilities for embankments, canals, regulators, and drains are often spread across agencies, while operational budgets compete with many other urgent needs. Maintenance work is typically invisible when it succeeds and highly visible when it fails therefore it is difficult to prioritize.

At the same time, the hydrological system is placing growing stress on existing infrastructure. Sediment loads change river behavior, channels migrate, flood peaks become more volatile, and aging embankments are asked to perform beyond the conditions for which they were originally designed. These pressures accumulate quietly over time, often without a clear triggering event.

When a high-flow event occurs, it exploits these accumulated weaknesses. An embankment breach or structural failure is rarely the result of a single storm; it is the outcome of years of gradual degradation interacting with a moment of hydrological stress.

At this point, the information and decision system shifts rapidly into crisis mode. Emergency response mechanisms are activated, often with considerable professionalism and commitment under extremely difficult conditions. Lives are saved, relief is mobilized, and immediate damage is contained as best as possible.

However, once the emergency phase subsides, attention naturally turns toward visible solutions. Political leaders, affected communities, and implementing agencies face strong pressure to demonstrate action. In this context, new infrastructure—raising embankments, strengthening bunds, constructing spurs or protective works—becomes the most tangible response.

These projects are often technically sound and urgently needed. Yet the socioeconomic and institutional context in which they are approved frequently emphasizes delivery over long-term care. Operation and maintenance requirements are acknowledged, but not always secured through sustained financing or clear institutional ownership.

Meanwhile, communities living behind these structures bear the residual risk. They adapt as best they can, often assuming that the new works will provide long-term protection, even when underlying vulnerabilities remain. The result is a reinforcing loop:

- maintenance gaps increase vulnerability;
- hydrological stress triggers failure;
- emergency response demands rapid action;
- new projects are delivered;
- and long-term maintenance once again struggles for attention.

This loop persists not because the system's incentives and constraints repeatedly pull decisions in this direction. Breaking the loop requires not just better engineering, but changes in how maintenance, risk, and long-term resilience are valued across all five subsystems.

### Senge Pattern: "Shifting the Burden"

The system relies on building new infrastructure (quick fixes) instead of addressing the underlying maintenance problem. The immediate response alleviates symptoms (flood impacts, embankment breaches) but reinforces the dependency on capital works while neglecting long-term preventive maintenance.

Pakistan's repeated investment in new embankments after failures illustrates a classic Shifting the Burden loop. The visible "solution" provides short-term relief but makes the system increasingly dependent on repeated interventions, without strengthening the maintenance subsystem or building community resilience.

## 3.2 Limits to Growth: Urban Growth → Blocked Drainage → Recurrent Flooding → Protective Works → More Growth

Urbanization is one of the most powerful drivers reshaping Pakistan's water system. Cities are engines of economic opportunity, service provision, and social mobility. Yet urban growth also transforms hydrology in ways that are often poorly aligned with planning and governance capacities.

From a socioeconomic and land-use perspective, rapid population growth and housing demand push development outward, frequently into low-lying areas and natural drainage corridors. These locations are attractive precisely because land is cheaper and initially accessible. In many cases, development occurs incrementally and informally, well ahead of formal planning and infrastructure provision.

As cities expand, the hydrological system responds predictably. Natural infiltration declines as surfaces are sealed. Runoff volumes increase. Flow paths that once conveyed stormwater safely through wetlands, channels, or open land become obstructed or disappear entirely. Rainfall events that would previously have been absorbed or drained gradually now produce rapid accumulation of water in streets, neighborhoods, and low-lying basins.

The institutional system often struggles to keep pace with these changes. Zoning regulations, where they exist, are difficult to enforce under intense housing pressure. Responsibilities for urban drainage are typically fragmented across municipal departments, development authorities, and utility agencies, each operating with limited mandates and resources. Drainage, in particular, tends to receive attention only after failure becomes visible.

When flooding occurs, the information and decision system again shifts into response mode. Flooded roads, damaged homes, and public disruption generate immediate demand for action. The most practical and politically feasible response is the construction of new drains, pumping stations, culverts, or protective embankments. These interventions often succeed in reducing short-term risk and restoring functionality.

However, the success of these protective works can create a secondary effect. By reducing visible flood risk, they make adjacent land more attractive for further development. Construction accelerates behind the new protections, often without corresponding upgrades to drainage capacity or land-use controls. Over time, exposure increases even as protection improves.

For vulnerable communities, particularly those in informal settlements, this loop carries disproportionate consequences. These groups are often the first to settle in flood-prone areas and the last to benefit from formal protection or drainage improvements. Their adaptive capacity—through elevation of homes, temporary barriers, or social networks—becomes a critical but fragile component of system resilience.

The resulting pattern is a reinforcing loop:

- urban growth increases runoff and blocks drainage;
- flooding triggers protective investments;
- protection enables further growth;
- and overall exposure continues to rise.

The loop is not "failure"—it is a predictable outcome of growth that outpaces regulation and drainage planning. This dynamic is not unique to Pakistan. It is a common feature of rapidly growing cities worldwide. The challenge lies not in stopping urban growth, but in aligning land-use planning, drainage design, and institutional coordination so that protection reduces risk rather than postponing it.

### Senge Pattern: "Limits to Growth"

Urban expansion initially brings economic gains and development, but physical and institutional constraints—drainage capacity, regulatory enforcement, and floodplain limitations—slow the benefits and amplify risk. Growth hits practical limits that eventually feed back into the system as flooding and exposure.

The loop of urban growth and protective works demonstrates Limits to Growth. Short-term protection allows further expansion, but each cycle increases exposure until the system's capacity to absorb additional growth is constrained by drainage, governance, or resilience limits.

### 3.3 Escalation: Groundwater Reliance → Falling Water Tables → Rising Costs → Water-Intensive Cropping

Groundwater plays a central role in Pakistan's water system. For millions of farmers, it provides reliability and flexibility that surface water alone cannot offer. Particularly in areas where canal supplies are variable or rotational, groundwater has functioned as a critical buffer against uncertainty.

From the perspective of the hydrological system, however, sustained abstraction has long-term consequences. Aquifers respond slowly but predictably to continuous pumping. Water tables decline, pumping depths increase, and in some regions water quality deteriorates through salinity or contamination. These changes are incremental, often unnoticed at first, but difficult to reverse once established.

At the socioeconomic level, farmers' decisions are largely rational. Crop choices are shaped by market demand, price stability, access to inputs, and risk. Water-intensive crops often provide the most reliable income, especially where alternatives are limited. As groundwater becomes more expensive to extract, households rarely reduce demand; instead, they invest in deeper wells, larger pumps, or shared extraction systems to maintain production.

The institutional system has limited leverage over this process. Groundwater abstraction remains largely unregulated, not because its importance is unrecognized, but because monitoring millions of private wells is technically, politically, and administratively challenging. Formal allocation mechanisms that work for surface water are difficult to replicate for underground water.

Meanwhile, the information and decision system struggles to keep pace. Data on abstraction volumes, recharge rates, and cumulative impacts are sparse or fragmented. As a result, declining groundwater levels are often treated as a local or temporary issue rather than a basin-scale trend requiring coordinated action.

For households and communities, the consequences are absorbed through the resilience subsystem. Rising pumping costs increase debt, reinforce inequality between farmers who can afford deeper wells and those who cannot, and reduce the capacity to adapt to other shocks such as floods or price fluctuations. What began as an adaptation to surface water uncertainty gradually becomes a dependency that narrows future options.

The reinforcing loop is subtle but powerful:

- unreliable surface supplies encourage groundwater use;
- groundwater levels decline;
- extraction becomes more costly;
- farmers intensify water use to secure livelihoods;
- and pressure on aquifers increases further.

This loop is not driven by overuse in isolation, but by the interaction of hydrology, markets, institutional constraints, and risk management strategies at the farm level. Addressing it requires alternatives that reduce risk for farmers, not just limits on pumping. What begins as a positive adaptation—relying on tube wells—can gradually become a dependence that deepens stress on both households and aquifers. Again, a reinforcing loop, but one built on rational decisions by millions of farmers acting in good faith.

#### Senge Pattern: "Escalation"

Individual farmers' rational responses to uncertainty—pumping more groundwater—interact in ways that escalate stress on aquifers. Each actor responding to perceived scarcity amplifies the problem for all. The reinforcing nature of the loop produces increasing costs, depletion, and long-term dependency.

Groundwater overuse is a classic escalation pattern. What starts as adaptive behavior for a single farm escalates across the system, leading to basin-wide aquifer stress and higher extraction costs. Without system-wide feedback, every rational decision makes the overall problem worse.

### 3.4 Limits to Success: Limited Local Resilience → Higher Disaster Losses → Relief-Oriented Budgets → Underinvestment in Prevention

The final interaction pattern brings the fifth subsystem—community and system resilience—into sharp focus. While Pakistan has developed substantial national capacity for disaster response, resilience at the local level remains uneven, shaped by poverty, exposure, and limited access to resources.

From a resilience perspective, the ability of households and communities to prepare for, withstand, and recover from floods or droughts varies widely. Early evacuation, temporary protection measures, savings, insurance, and social support networks all influence outcomes. Where these capacities are weak, even moderate hazards can produce severe losses.

These vulnerabilities intersect with the hydrological system, where floods, droughts, and extreme rainfall events recur with increasing variability. The hazard itself may not be exceptional, but its impact is magnified by where and how people live—often in low-lying areas, floodplains, or informal settlements where alternatives are limited.

When disasters occur, the institutional system responds under intense public and political pressure. Relief operations—emergency shelter, food distribution, medical support, compensation—are essential and often delivered with considerable commitment. In such moments, immediate human needs understandably take precedence over longer-term risk reduction.

The information and decision system reinforces this focus. Damage assessments, media coverage, and political accountability are concentrated on visible losses rather than avoided ones. Investments in prevention, maintenance, or preparedness are harder to justify when their success is measured by events that do not happen.

Over time, this shapes budget priorities. Relief and recovery absorbs a substantial share of available resources, leaving limited fiscal space for preventive measures such as floodplain management, drainage maintenance, early-warning dissemination at community level, or livelihood diversification. Prevention is recognized as desirable, but difficult to sustain politically and financially.

For affected communities, this dynamic translates into a persistent state of exposure. Recovery is partial, assets are depleted, and adaptive capacity erodes.

When the next event occurs, losses are again high—not because nothing was done, but because the system as a whole is oriented toward response rather than risk reduction.

The reinforcing loop is clear:

- limited local resilience increases disaster impacts;
- high losses drive relief-focused responses;
- relief dominates budgets and attention;
- preventive investment remains constrained;
- vulnerability persists.

This pattern does not reflect neglect or indifference. The system behaves according to its structure. It reflects the realities faced by governments operating under fiscal constraints, political expectations, and recurrent hazards.

Strengthening resilience is not about replacing relief, but about gradually rebalancing the system so that preparedness and prevention become integral parts of how risk is managed.

### Senge Pattern: "Limits to Success"

Relief-focused responses appear effective initially, but they impose limits on building long-term resilience. Resources and attention are absorbed by emergency spending, reducing investment in prevention and adaptive capacity. Over time, repeated crises show diminishing returns: high visibility of response does not reduce vulnerability.

Pakistan's emphasis on relief over prevention exemplifies Limits to Success. Initial effectiveness of relief masks the underlying vulnerability, eventually constraining the system's ability to reduce risk and improve resilience in a sustainable way.

## 3.5. A clear picture emerging

When these interaction patterns are viewed together, a coherent picture emerges. Pakistan's water challenges do not stem from a lack of effort, expertise, or commitment. On the contrary, they reflect a system in which each subsystem responds rationally to the pressures it faces.

- Institutions manage crises with the tools and mandates available to them.
- Communities adapt in ways that protect livelihoods in the short term.
- Urban areas grow in response to economic demand.
- Farmers rely on groundwater to reduce risk.
- Decision-makers prioritize actions that are visible, fundable, and politically feasible.

Individually, these responses make sense. Collectively, they produce outcomes that are difficult to sustain.

- Fragmentation across mandates and scales makes coordination challenging.
- Short-term financing cycles favor reactive spending over long-term care.
- Land-use and agricultural growth reshape hydrology faster than institutions can adapt.
- Information often arrives too late, or in forms that are difficult to translate into action.
- Communities absorb a disproportionate share of residual risk.

These conditions echo long-standing assessments that Pakistan's water system is under increasing pressure, with limited fiscal space and a natural resource base experiencing gradual but persistent stress. Yet they also reveal where change is possible.

Floods, droughts, and groundwater decline are not signs of systemic collapse. They are signals—indicating where incentives misalign, where feedback loops reinforce vulnerability, and where targeted interventions could shift the system onto a more resilient path.

The purpose of understanding these interactions is not to assign blame, but to identify leverage points. The next section builds on this system's view to explore how policy, planning, and decision-making can begin to realign the five subsystems toward long-term resilience.

Taken together, the four loops reveal a coherent pattern: Pakistan's water sector behaves in ways that are predictable once we understand how the subsystems interact. Each subsystem responds rationally to its own pressures—institutions manage crises with the tools available, communities adapt to local risks, urban areas expand in response to opportunity, and farmers rely on groundwater to reduce uncertainty. Yet these well-intentioned behaviors interact in ways that create reinforcing cycles, some of which produce unintended consequences over time.

Viewed through the lens of Peter Senge's system archetypes, each loop reflects a recognizable pattern:

- Reliance on new infrastructure instead of maintenance mirrors Shifting the Burden.
- Urban expansion constrained by drainage and institutional limits illustrates Limits to Growth.
- Escalating groundwater use exemplifies Escalation, where rational individual decisions amplify collective risk.
- Relief-focused responses that crowd out prevention show Limits to Success, where early effectiveness masks underlying vulnerability.

Recognizing these archetypes highlights that the system's challenges are not simply the result of isolated decisions or occasional failures. They emerge from structural dynamics that repeat predictably, shaping the timing, magnitude, and distribution of impacts across the basin.

These patterns also reveal where leverage exists: by identifying the loops and understanding the feedback, policymakers, institutions, and communities can design interventions that gradually shift the system toward greater resilience, rather than relying solely on reactive responses.

Floods, groundwater decline, and urban inundation are not signs of systemic failure—they are signals. They indicate where attention, learning, and coordinated action can make the most difference, turning recurring challenges into opportunities for transformation.

# 4. Breaking Reinforcing Loops

## Learning, Adaptation, and Reform in Pakistan's Water Sector

### 4.1 Introduction – From Patterns to Leverage

Section 3 showed that Pakistan's water sector challenges—floods, groundwater depletion, urban inundation, and infrastructure stress—are not random or isolated events. They emerge from predictable interactions among five subsystems: hydrology, institutions, socioeconomic behavior, information and decision-making, and community resilience. When viewed through Peter Senge's archetypical patterns, these loops reveal recurring system behaviors: reliance on short-term fixes (Shifting the Burden), constraints on urban expansion (Limits to Growth), escalating groundwater use (Escalation), and relief-focused responses that mask underlying vulnerability (Limits to Success).

Recognizing these patterns helps us understand why the system behaves as it does. Yet understanding alone does not create change. Systemic loops will continue unless the conditions for learning, adaptation, and coordinated action are established. To guide this process, we turn to the Lippitt-Knoster model for complex change.

Originally developed to support organizational transformation, the model identifies six conditions necessary for effective change: vision, consensus, skills, incentives, resources, and an action plan. Each element addresses a barrier that can prevent systemic improvement:

- Vision provides a clear, shared long-term goal.
- Consensus ensures that all stakeholders agree on priorities and objectives.
- Skills build the capacity to implement change effectively.
- Incentives align behaviors with desired outcomes.
- Resources provide the financial, technical, and human means to act.
- Action Plan translates strategy into coordinated, practical steps.

When any one of these elements is missing—whether vision, consensus, skills, incentives, resources, or an action plan—efforts to change the system often falter, producing confusion, frustration, or initiatives that fail to gain traction.


**Figure 02.** Lippitt-Knoster model for complex change

Applied to Pakistan's water sector, the Lippitt-Knoster model connects the diagnosis of systemic loops to practical interventions, highlighting where investments in governance, capacity, and coordination can shift reinforcing cycles toward sustainability. Combined with Senge's archetypes, it provides a dual lens: one to understand why the system behaves as it does, and another to guide how it can evolve.

The following sections explore these insights in detail. Section 4.2 identifies leverage points in each loop, showing where vision, skills, incentives, resources, and action can be mobilized to transform patterns of vulnerability into pathways for resilience. Subsequent sections examine institutional learning, community-based resilience, and adaptive policy as mechanisms to put these principles into practice.

## 4.2 Recognizing Feedback Loops and Leverage Points

Each of the systemic loops identified in section 3 represents a recurring pattern that reinforces vulnerability. When viewed through Peter Senge's archetypes, these loops reveal predictable dynamics. The Lippitt-Knoster model then helps us translate these insights into actionable leverage points: the conditions needed for effective, coordinated change.

### 4.2.1 Shifting the Burden: Maintenance Gaps → Infrastructure Stress → Emergency Response → New Projects

Each of the systemic loops identified in section 3 represents a recurring pattern that reinforces vulnerability. When viewed through Peter Senge's archetypes, these loops reveal predictable dynamics. The Lippitt-Knoster model then helps us translate these insights into actionable leverage points: the conditions needed for effective, coordinated change.

### Senge Archetype: Shifting the Burden

**Narrative and Leverage:**
The system repeatedly addresses embankment breaches and infrastructure stress with new capital works, rather than tackling the root problem: maintenance. This short-term response alleviates immediate pressure but reinforces dependency on reactive investments.

To shift this pattern, we need:

- **Vision:**
  A shared understanding among agencies and stakeholders that preventive maintenance is as important as new construction.

- **Consensus:**
  Agreement across federal, provincial, and local institutions on maintenance priorities.

- **Skills:**
  Technical and managerial capacity to plan and execute long-term maintenance programs.

- **Incentives:**
  Recognition and accountability for effective maintenance, not just new projects.

- **Resources:**
  Budget allocations and personnel dedicated to preventive care.

- **Action Plan:**
  Clear schedules and monitoring systems integrated into infrastructure management.

By addressing these points, the Shifting the Burden loop can gradually transform into a balanced cycle that reduces both risk and long-term costs.

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### 4.2.2 Limits to Growth: Urban Growth → Blocked Drainage → Recurrent Flooding → Protective Works → More Growth

#### Senge Archetype: Limits to Growth

**Narrative and Leverage:**
Urban expansion brings economic opportunity but often exceeds the capacity of natural drainage systems and enforcement mechanisms. Protective works mitigate immediate flooding, yet enable further growth in vulnerable areas, increasing exposure.

Leverage points include:

- **Vision:**
  A long-term strategy for sustainable urban expansion aligned with natural drainage.

- **Consensus:**
  Coordination among urban planners, municipal authorities, and communities.

- **Skills:**
  Expertise in drainage design, enforcement, and integrated urban planning.

- **Incentives:**
  Policies that reward development within safe zones and discourage construction in flood-prone corridors.

- **Resources:**
  Funding for preventive infrastructure and monitoring systems.

- **Action Plan:**
  Phased urban development linked to drainage capacity upgrades and risk assessments.

Targeting these points can convert urban expansion from a reinforcing vulnerability loop into a managed, adaptive growth process.

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### 4.2.3 Escalation: Groundwater Reliance → Falling Water Tables → Rising Costs → Water-Intensive Cropping

#### Senge Archetype: Escalation

**Narrative and Leverage:**
Farmers respond rationally to uncertain canal supplies by pumping groundwater. When many actors do this simultaneously, it creates escalating pressure on aquifers, higher extraction costs, and increasing dependency.

Key leverage points are:

- **Vision:**
  Sustainable groundwater use at the basin scale.
- **Consensus**:
  Agreement among farmers, local authorities, and water institutions on abstraction limits and crop choices.
- **Skills**:
  Monitoring, modeling, and water-efficient agriculture.
- **Incentives:**
  Pricing, subsidies, or recognition that reward sustainable extraction practices.
- **Resources:**
  Measurement tools, alternative water sources, alternative livelihood options, and financial support for adaptation.
- **Action Plan:**
  Coordinated water allocation, awareness campaigns, and adaptive regulation.

These interventions can slow or reverse the Escalation loop, protecting both aquifers and livelihoods.

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#### 4.2.4 Limits to Success: Limited Local Resilience → Higher Disaster Losses → Relief-Oriented Budgets → Underinvestment in Prevention

**Senge Archetype: Limits to Success**

**Narrative and Leverage:**
Communities with limited capacity to prepare for hazards experience higher losses, which shifts institutional focus and resources toward relief. Preventive investment remains constrained, and vulnerability persists.

Leverage points include:

- **Vision:**
  Communities and institutions capable of reducing risk proactively.
- **Consensus:**
  Recognition of prevention as a priority alongside relief.
- **Skills:**
  Local disaster preparedness, risk interpretation, and adaptive response planning.
- **Incentives:**
  Budget allocations and recognition linked to preventive actions and resilience outcomes.
- **Resources:**
  Infrastructure, early warning systems, and community support mechanisms.
- **Action Plan:**
  Integration of risk reduction into planning, budgeting, and community engagement.

By addressing these elements, the system can gradually shift from reactive relief toward sustained, proactive resilience.

## Synthesis:

### 4.3 Enhancing Institutional Learning

The loops and feedbacks identified in section 3 highlight how Pakistan's water sector often responds reactively to emerging pressures. Achieving lasting change requires institutions to function as learning organizations, capable of anticipating challenges, interpreting feedback, and coordinating across layers of government. Institutional learning depends on strengthening monitoring systems, fostering collaboration, and aligning incentives to encourage proactive, adaptive behavior.

Effective monitoring and feedback are the foundation of learning. Institutions must integrate hydrological and meteorological data to anticipate floods, droughts, and groundwater stress. Early warning systems should reach local authorities and communities in time to act, and decision-support tools should enable planners to evaluate trade-offs across multiple interventions. By improving the flow of information, institutions can act strategically rather than relying solely on reactive measures.

Collaboration across agencies further enhances learning. Fragmented mandates, overlapping responsibilities, and siloed incentives often amplify reinforcing vulnerabilities. By establishing joint planning mechanisms, knowledge-sharing platforms, and cross-department evaluations of past interventions, agencies can develop collective memory and coordinate responses more effectively. Cross-agency collaboration reduces duplication, clarifies responsibilities, and ensures that interventions are coherent across the system.

Incentive structures play a pivotal role. Institutions frequently reward visible, short-term outputs such as new infrastructure or emergency response rather than preventive maintenance or adaptive management. Aligning incentives with long-term system goals—including resilience, sustainability, and adaptive capacity—encourages institutions to invest in preventive measures and evidence-based interventions.

Comparative experience demonstrates the power of institutional learning in practice. Thailand's integrated flood forecasting system improved coordination and lead times across provinces. Gujarat, India, used basin-level groundwater management committees to facilitate cooperative abstraction and reduce aquifer stress. Jakarta adopted scenario-based urban drainage planning to manage recurrent flooding amid rapid urban growth. At a larger scale, The Netherlands' dynamic adaptive delta management engages all relevant sectors and actors to co-develop shared visions and flexible action plans that evolve over time, while Bangladesh's Delta Plan 2100 similarly combines multi-sector planning with adaptive management principles, testing flexible measures for flood control, water allocation, and ecosystem management as conditions change.

Success in these cases depends on the six conditions of the Lippitt-Knoster model: a clear vision, consensus among stakeholders, skills to implement change, aligned incentives, sufficient resources, and a living action plan. When these elements are in place, institutions can detect vulnerabilities early, respond strategically, and gradually shift reinforcing loops toward balancing cycles that enhance system resilience.

### 4.4 Building Resilience into Communities and Systems

While institutional reforms are essential, communities themselves are critical actors in shaping outcomes. Section 3 illustrated how limited local resilience can amplify disaster impacts, reinforcing cycles of relief-oriented spending and underinvestment in prevention. Strengthening resilience at the community level is therefore a key complement to institutional learning.

Resilient communities are able to anticipate, absorb, and recover from hazards, reducing pressure on institutions and helping transform reinforcing loops into balancing ones."

Practical measures include disaster preparedness training, local risk assessments, and livelihood diversification to reduce dependency on a single resource. These strategies directly address vulnerabilities while enhancing adaptive capacity at the local level.

Community participation further strengthens resilience. Engaging local stakeholders in planning, monitoring, and decision-making ensures that interventions are contextually relevant and socially accepted. Local water management committees, co-designed flood protection measures, and scenario-based simulations allow communities to play an active role in shaping interventions. Participation builds trust, strengthens consensus, and ensures that action plans are feasible and adaptive—directly reflecting Lippitt-Knoster principles.

Community resilience interventions also link directly to systemic loops identified in section 3. By reducing reliance on emergency relief, communities free institutional resources for preventive action. Participation in drainage maintenance or zoning enforcement slows reinforcing urban flooding cycles. Education on groundwater conservation and diversified livelihoods eases pressure on aquifers. These interventions shift reinforcing vulnerability loops into balancing mechanisms, creating more stable and resilient outcomes.

Comparative examples reinforce these lessons. In The Netherlands, participatory adaptive delta management engages communities alongside institutions, ensuring that flood defenses and land-use plans remain flexible and responsive. Bangladesh's Delta Plan 2100 similarly incorporates local engagement in flood risk mapping, early warning dissemination, and adaptive livelihood planning. These cases demonstrate that resilience is not just about infrastructure but about capacitating people to act, adapt, and collaborate.

### 4.5 Scenario Planning and Adaptive Policy

Understanding systemic patterns and strengthening institutional and community capacity provides a foundation, but uncertainty—climate variability, urban growth, groundwater pressures, and socioeconomic change—requires planning that is flexible and forward-looking. Scenario planning and adaptive policy offer tools to anticipate multiple futures, test interventions, and adjust strategies over time.

Scenario planning allows decision-makers to explore plausible trajectories, such as variations in rainfall, urban expansion, or groundwater availability, and evaluate how interventions might perform under each scenario. This approach reveals potential unintended consequences and highlights where reinforcing loops may persist or be transformed. When viewed through Senge's archetypes, scenario planning also clarifies which systemic patterns—such as Shifting the Burden or Limits to Growth—are most likely to emerge and where interventions can have the greatest effect.

Adaptive policy embeds learning and flexibility into governance. Interventions are treated as experiments:

plans are monitored, evaluated, and adjusted as new information emerges, as climatic and hydrological conditions change, and as social and economic contexts evolve. Integration across subsystems ensures that interventions consider hydrology, infrastructure, institutions, communities, and decision-support systems together, avoiding unintended consequences and reinforcing positive feedback.

Examples from practice illustrate the potential of this approach. The Netherlands uses dynamic adaptive delta management to test infrastructure, land-use, and governance strategies under multiple scenarios, updating policies continuously based on monitoring and stakeholder feedback. Bangladesh's Delta Plan 2100 applies a similar scenario-based approach to coordinate flood management, water allocation, and ecosystem restoration, while maintaining flexibility to respond to evolving conditions.

When scenario planning and adaptive policy are applied together, they operationalize systemic insights into flexible, actionable strategies. They transform static plans into living strategies, allowing the water sector to respond proactively to challenges and continuously improve over time. This approach ensures that reinforcing loops of vulnerability are addressed strategically, while balancing loops of resilience are strengthened across the system.

## 4.6 Synthesizing Lessons and Recommendations

Across Sections 4.3 to 4.5, a consistent set of lessons emerges: systemic challenges arise from interacting subsystems and reinforcing loops, rather than from a lack of effort or expertise. Recognizing this allows policymakers and practitioners to focus on interventions with the highest leverage, targeting loops that shape long-term outcomes.

Strengthening institutional learning equips agencies to anticipate and respond strategically. By aligning vision, building consensus, developing skills, creating incentives, securing resources, and implementing coordinated action plans, institutions can act as learning organizations capable of shifting reinforcing loops toward balancing cycles. Community engagement complements these reforms by building local capacity, enabling residents to participate actively in planning, preparedness, and resource management. Together, institutional and community learning reduce vulnerability and improve the effectiveness of interventions.

Scenario planning and adaptive policy then translate these insights into practical action. By testing interventions under multiple plausible futures and adjusting strategies iteratively, policymakers can anticipate unintended consequences, remain flexible, and integrate interventions across hydrology, infrastructure, institutions, and communities. Comparative experiences—from Thailand, Gujarat, Jakarta, The Netherlands, and Bangladesh—demonstrate the power of combining learning, resilience, and adaptive policy to achieve sustainable, system-wide outcomes.

The recommendations for action flow naturally from this integrated understanding. Interventions should prioritize high-leverage loops, foster institutional learning through the Lippitt-Knoster elements, actively engage communities, apply scenario-based planning to anticipate uncertainty, and embed monitoring and feedback at every level. Together, these measures provide a roadmap for transforming Pakistan's water sector from a system of reactive cycles into one that is learning, adaptive, and resilient, capable of responding to current pressures while preparing for future challenges.

## 4.7 Conclusion

Section 4 has shown that understanding systemic patterns, strengthening institutional and community capacity, and applying adaptive, scenario-based policies are not separate tasks—they are mutually reinforcing strategies for sustainable water management. The loops, feedbacks, and archetypical patterns identified in Section 3 do not merely describe problems; they reveal the levers through which change is possible.

By fostering institutional learning, agencies can anticipate pressures, coordinate across silos, and align incentives with long-term system goals.
By building community resilience, households and local organizations become active participants in shaping outcomes, reducing vulnerability and reinforcing adaptive behaviors.

By embracing scenario planning and adaptive policy, the sector gains the flexibility to respond to uncertainty, test interventions before large-scale implementation, and adjust strategies iteratively as conditions evolve. The experiences of Thailand, Gujarat, Jakarta, the Netherlands, and Bangladesh illustrate that even complex, multi-layered water systems can learn, adapt, and transform. These cases highlight the importance of integrating vision, consensus, skills, incentives, resources, and action plans—the Lippitt-Knoster elements—into every level of planning and decision-making, ensuring that adaptive strategies are both feasible and effective.

Taken together, the lessons of section 4 reinforce a simple but powerful message: Pakistan's water sector is not fixed. Its vulnerabilities are not inevitable failures, nor are its reinforcing loops insurmountable. By recognizing systemic patterns, applying lessons from learning organizations, and embedding adaptive policies and community engagement into everyday practice, the sector can shift toward resilience, sustainability, and long-term adaptability.

This forward-looking perspective sets the stage for subsequent sections, which explore how specific interventions, planning approaches, and policy reforms can operationalize these lessons in practice. The system is not a static structure to be controlled; it is a living network that, when understood and guided thoughtfully, can evolve to meet both current challenges and the uncertainties of the future.

## 4. Breaking Reinforcing Loops

As this section draws to a close, it is worth stepping back to reflect on what Pakistan's water sector teaches us about complexity, adaptation, and the potential for transformation. The patterns explored in section 3 and 4 reveal a system shaped not by individual failures, but by the interactions of five interdependent subsystems: hydrology and environment, institutions and governance, socioeconomic and land-use dynamics, information and decision-making, and community resilience. These subsystems, with their reinforcing loops and feedbacks, create both challenges and opportunities. Floods, groundwater depletion, urban inundation, and infrastructure stress are not anomalies; they are the system speaking. Yet within these patterns lie the points of leverage where change is possible.

One of the most important lessons is that systemic problems cannot be solved in isolation. Institutional learning and community resilience are complementary: when institutions improve coordination, share knowledge, and adapt their policies, communities gain the tools and support to act proactively, reducing their vulnerability. Conversely, empowered communities provide critical feedback, local knowledge, and adaptive capacity that enhance institutional decision-making. Together, they form a reinforcing loop of learning and adaptation, turning vulnerability into resilience.

Another central insight is the value of adaptive, scenario-based approaches. In a world of uncertainty—shifting rainfall patterns, expanding cities, variable groundwater supplies, and evolving socioeconomic pressures—static plans are insufficient. Scenario planning and iterative adaptation allow policymakers and practitioners to anticipate multiple futures, test interventions, and adjust strategies in real time. This approach transforms knowledge into action, ensuring that decisions remain robust under changing conditions and that reinforcing vulnerabilities are gradually shifted toward balancing outcomes.

This section also emphasizes that change is not simply a matter of resources or technical solutions. Success depends on aligning vision, consensus, skills, incentives, resources, and action plans, reflecting the Lippitt-Knoster model for complex change. It requires a mindset that embraces learning, experimentation, and collaboration across sectors and scales. Comparative experiences—from the Netherlands' adaptive delta management to Bangladesh's Delta Plan 2100, and examples in Thailand, Gujarat, and Jakarta—demonstrate that even complex water systems can evolve when actors act collectively and adaptively.

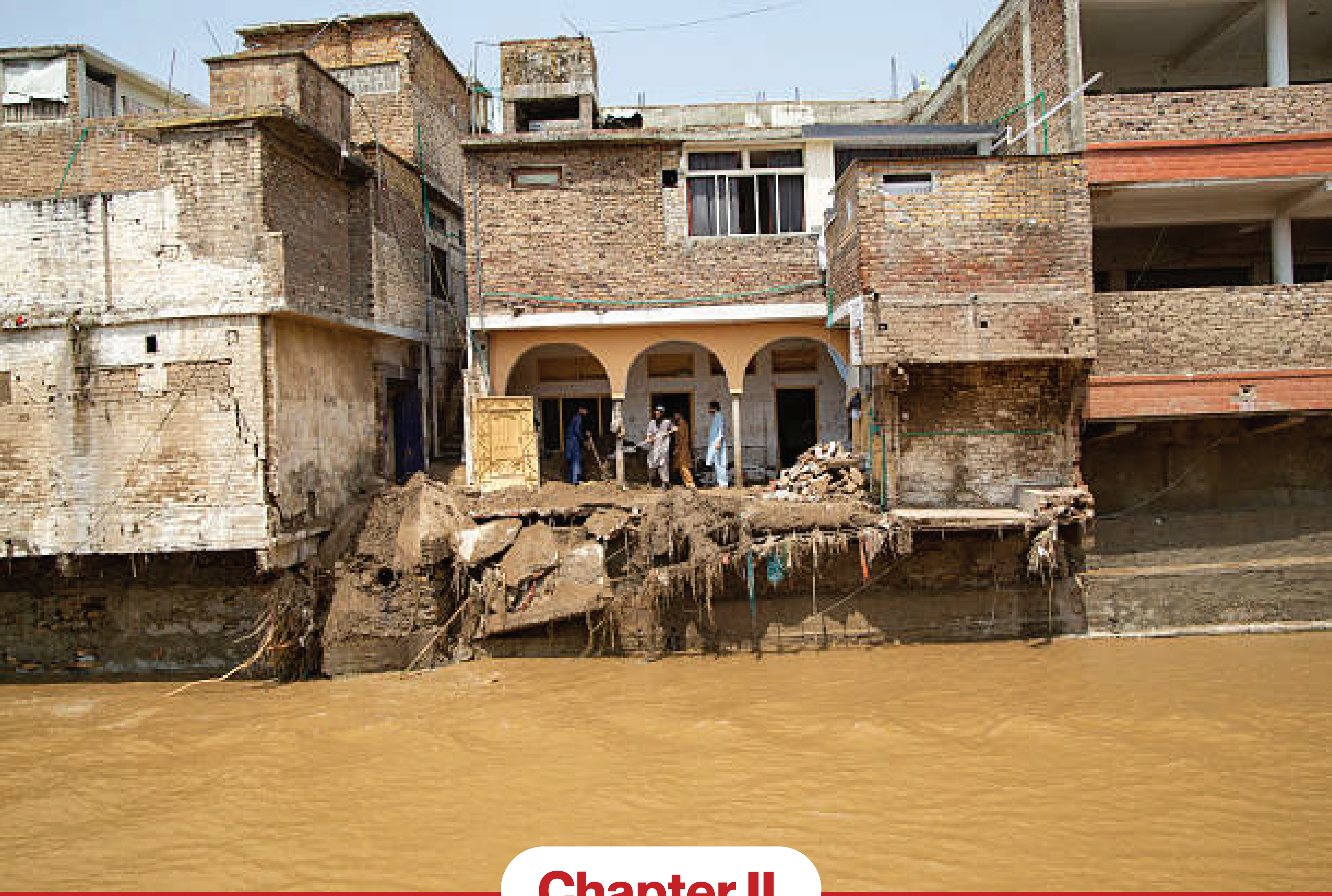
For Pakistan, the pathway forward is clear. By targeting high-leverage loops, investing in institutional learning, building community resilience, and applying adaptive, scenario-based policies, the water sector can transition from reactive cycles to a system that is flexible, resilient, and sustainable. These are not theoretical concepts; they are actionable strategies grounded in the realities of the basin and the experiences of other complex water systems.

Beyond Pakistan, these lessons carry relevance for deltas, river basins, and water systems worldwide. Climate change, urbanization, and resource pressures are universal challenges, and the principles outlined here—systems thinking, learning organizations, adaptive management, and community engagement—offer a roadmap for navigating complexity anywhere.

Finally, this section is an invitation to reframe how we view water systems. They are not static infrastructures to be controlled, but living networks shaped by interactions, feedback, and human decisions. Recognizing patterns, understanding interdependencies, and acting adaptively opens pathways to a future where floods, droughts, and water stress are not merely crises but signals guiding us toward smarter, more resilient management.

The system is not fixed. By embracing learning, collaboration, and adaptability, Pakistan—and indeed any water-dependent region—can move toward a water future that is sustainable, equitable, and resilient, ready to meet both today's challenges and the uncertainties of tomorrow.

The path forward is clear: by embracing systems thinking, fostering institutional learning, empowering communities, and applying adaptive strategies, Pakistan—and other water-dependent regions—can transform challenges into opportunities. The future of water management is not about controlling a fixed system; it is about learning with it, adapting to it, and shaping it collectively. Every decision, every investment, and every act of collaboration becomes part of a living process that moves the system toward resilience, sustainability, and equity. The opportunity is now: to turn knowledge into action, and to let the system itself guide us toward a water future that is robust, adaptive, and shared by all.



Chapter II

# WHY FLOODS BECOME DISASTERS

Dr Muhammad Arfan

# Flood and Flood's Typology in Pakistan

Pakistan's vulnerability to floods is rooted in its unique geography, which features the world's highest mountains alongside vast plains. The major rivers of the Indus River Basin (IRB)—the Indus itself and its main tributaries (Jhelum, Chenab, Ravi, Beas, and Sutlej)—all originate in the Himalayas. The Indus River flows through the Karakoram ranges, entering Pakistan in Gilgit-Baltistan, while the four tributaries traverse the Kashmir valley before reaching the Punjab plains. These waterways eventually converge, forming the Indus River Basin, which encompasses approximately 65% of Pakistan's territory and supports over 80% of its population.

In addition to these main rivers, numerous other major rivers, such as the Swat, Kunhar, and Kabul, descend from the Karakoram and Hindukush ranges, along with countless medium and smaller rivers that crisscross the northern areas of Khyber Pakhtunkhaw and Gilgit-Baltistan.

This diverse landscape—comprising steep, extremely high, snow-clad northern mountain ranges, rugged western mountain ranges, and rapidly expanding, poorly planned urban centers—results in Pakistan experiencing several distinct types of floods: riverine, flash floods, glacial lake outburst floods (GLOFs), coastal floods, cloudburst-induced flooding, and urban floods.

In the following section we would briefly explain the flood's typology:

## Riverine Floods

Riverine floods primarily result from heavy monsoon rainfall, often compounded by snow and glacier melt, leading to river flows that exceed safe capacity. The monsoon season, typically from July to September, involves winds from the Bay of Bengal moving toward the western Himalayan foothills. These winds sometimes carry intense depressions, causing large volumes of rain. Monsoon currents generally intensify by mid-July, peak in August, and recede in September, though they can occasionally persist later into the year. Rainfall initially concentrates in the eastern river basins (Beas, Sutlej, and Ravi) before moving westward into the rest of the Indus basin.

The severity of riverine flooding often increases at certain points when the high-water peaks from two or more rivers in the Indus system merge at confluence points, a phenomenon which has been observed throughout Pakistan's flood history.

## Flash Floods in Hill Torrents

Flash floods are characterized by their sudden onset and minimal warning time, typically occurring in semi-mountainous and mountainous terrain or adjacent regions. These events generally follow within six hours of intense rainfall in a catchment area. On the western side of the Indus River, the landscape around the Kirther and Koh-e-Suleman ranges is traversed by numerous hill torrents of varying sizes. Thirteen of these hill torrents are particularly hazardous due to the significant magnitude and frequency of their flooding. The destructive power of these flash floods stems from the enormous force they generate while rushing down steep slopes and through narrow gorges, leaving communities situated at the foothills of these mountains very little time to react. A notable example of severe flash flooding occurred in 2022 when the Gaj River overflowed, inundating the districts of Dadu and Jamshoro on the right bank of the Indus River.

## Urban Floods

Urban flooding has become a prevalent issue in Pakistani cities, distinct from riverine or flash floods. This type of inundation is primarily a result of poorly managed stormwater drainage infrastructure. The intense rainfall common during the monsoon season overwhelms urban centers because drainage networks are often undersized, clogged, or encroached upon, leaving inadequate natural channels for water runoff.

Major cities such as Karachi, Lahore, Faisalabad, Sialkot, Gujranwala, Multan, and Hyderabad are frequent victims of this problem. During the monsoon, streets rapidly turn into torrents, leading to the severe inundation of low-lying areas. This situation is further aggravated by a combination of factors, including high population density, unplanned urban development, and ineffective solid-waste management practices.

Another significant cause of urban flooding is the complete loss of green spaces within cities. With fewer areas to absorb rainfall, almost all the water rapidly turns into runoff.

## Glacial Lake Outburst Floods (GLOFs)

Climate change is causing glaciers in Pakistan's far north to melt rapidly, leading to another emerging threat: Glacial Lake Outburst Floods (GLOFs). GLOFs occur when meltwater accumulates, forming glacial lakes held back by ice or loose sediment dams. The sudden breach of these dams, often due to increased hydrostatic pressure, releases a massive volume of water. As the flood water bursts through narrow mountain valleys with tremendous force and speed, it has the power to obliterate anything and everything in its path which poses a major risk for the human settlements including old villages as well as any development infrastructure in its potential path. Multiple GLOF events have already been experienced in Gilgit-Baltistan and other northern regions of Pakistan.

## Cloudburst-Induced Flooding

Cloudburst induced flooding is also a fairly new phenomenon in Pakistan.Mereologically cloudburst is categorized when extremely intense, short-duration rainfall events occur over a smaller radius of the area then it triggers sudden, localized flooding, especially in mountainous and peri-urban regions.[1]

### Coastal Floods

Coastal flooding, often resulting from tropical cyclones or low-pressure systems, is triggered by powerful winds that drive seawater inland, a phenomenon known as a storm surge. These surges elevate sea levels and produce unusually high waves, leading to the inundation of coastal communities. In Pakistan, extreme weather in the Arabian Sea is the primary cause of such floods, making the coastal regions of Balochistan and Sindh highly susceptible. Although historically less frequent than riverine flooding, the intensity and occurrence of these coastal events are projected to rise due to shifting climate patterns in the Arabian Sea.

## Climate and Anthropogenic Drivers of Floods in the Indus Basin

There are three major large-scale climate interactions that significantly influence flooding in the Indus Basin. These interactions govern the monsoon's strength, the routes of moisture-laden air, and the intensity of rainfall events.

1. La Niña (cool phase of ENSO) typically strengthens the South Asian monsoon by enhancing convection over the Indian Ocean and driving moisture towards Pakistan.[2,3]

2. Positive Indian Ocean Dipole (IOD) events also contribute by warming the western Indian Ocean, intensifying moisture supply from the Arabian Sea and increasing rainfall over Pakistan.[4]

3. Recent literature emphasizes that thermal contrasts—such as land-ocean temperature gradients and regional heatwaves—act as strong forcing mechanisms drawing the Arabian sea moisture towards inland.[5] This mechanism has become more pronounced in recent decades due to rising land-surface temperatures and prolonged pre-monsoon heatwaves. The 2022 flood in Pakistan was an exemplary case study of this thermal forcing laden moisture movement from Arabian sea towards inland. An exceptional heatwave in March–May 2022 created strong low-pressure zones over Balochistan and Sindh. When monsoon systems finally arrived, this thermal gradient pulled moisture northward from the Arabian sea at an unprecedented scale. As a result, rainfall in Sindh and Balochistan reached 500–700% above normal, generating flooding in regions that historically receive minimal monsoon rainfall.[6]

There is a general consensus among the scientists that the anthropogenic activities in the Indus Basin are changing the monsoon mechanics. Carbon emission from the urban center and biomass burning reshaped the microphysics of cloud formation and thus, leading towards suppressing rainfall in some areas and increasing "cloudburst" phenomenon in some areas. The recent urban flooding in some cities like Sialkot city and KPK flooding in Buner and Shangla districts are examples of this phenomenon. The rising trend of high delta irrigated agriculture in the Indus Basin is also a key driver for altering the monsoon mechanics.

Academic research shows that expanded irrigated agriculture increases surface humidity and lowers surface temperature leading towards weakening monsoon circulation but increasing localized moisture recycling. Thus, this altered surface-climate interaction shifts moisture pathways, making certain regions more prone to intense rainfall.

The recent peer reviewed study[7] analyzed weather pattern as to what extent human-induced climate forcing reshaped the likelihood and intensity of heavy rainfall that led to urban flooding in the study region including the recent, most affected districts in the provinces of Punjab (Rawalpindi, Chakwal, Faisalabad, and Lahore) and Khyber Pakhtunkhwa (Peshawar valley) of Pakistan. The study concluded that the 30-day maximum rainfall over the study region is now approximately 22% more intense than it would have been, due to the burning of fossil fuels, and, to a smaller extent, deforestation. However, some realistic climate models suggest 40-80% more intense rainfall which makes the situation even worse.

The 2025 cloudburst-induced flooding in the Buner and Shangla districts highlights how the convergence of climate mechanics and land-use change creates a 'compound hazard.' This event triggered devastating torrents of boulders and debris that overwhelmed low-lying valley settlements, resulting in the loss of over 500 lives.

The 2025 monsoon also proved the climatic projections,[8,9] that Himalayan orography may become more permeable to monsoon flows under warm climate forcing. In 2025, meteorological analyses indicated, for the first time in recorded history, that monsoon moisture penetrated the Himalaya–Karakoram–Hindukush (HKH) barrier and spilled into parts of the Tibetan Plateau.[10] This suggests a major shift in atmospheric circulation patterns, likely driven by: intensified land-surface heating in the plains, weakened westerly winds, deeper monsoon depressions and increasing moisture content in the Arabian Sea.

1 Kuksina, L. V., Golosov, V. N., & Kuznetsova, Y. S. (2017). Cloudburst floods in mountains: State of knowledge, occurrence, factors of formation. Geography and Natural Resources, 38(1), 20-29.
2 Turner, A. G., & Annamalai, H. (2012). Climate change and the South Asian summer monsoon.
3 Kumar, K. K., Rajagopalan, B., & Cane, M. A. (1999). On the weakening relationship between the Indian monsoon and ENSO. Science, 284(5423), 2156-2159.
4 Shamim, T., Bhat, M. S., Alam, A., Allaie, A., & Ahsan, S. (2025). Impact of El Nino Southern Oscillation, Indian Ocean Dipole and North Atlantic Oscillation on the drought scenarios in the Upper Indus Basin. Theoretical and Applied Climatology, 156(4), 1-22.
5 Singh, D., Ghosh, S., Roxy, M. K., & McDermid, S. (2019). Indian summer monsoon: Extreme events, historical changes, and role of anthropogenic forcings. Wiley Interdisciplinary Reviews: Climate Change, 10(2), e571.
6 https://www.worldweatherattribution.org/climate-change-likely-increased-extreme-monsoon-rainfall-flooding-highly-vulnerable-communities-in-pakistan/
7 https://spiral.imperial.ac.uk/server/api/core/bitstreams/a0162fc8-0ed7-4d2e-944a-9ec76bf7666d/content
8 Boos, W. R., & Kuang, Z. (2010). Dominant control of the South Asian monsoon by orographic insulation versus plateau heating. Nature, 463(7278), 218-222.
9 Wu, F., Fang, X., Yang, Y., Dupont-Nivet, G., Nie, J., Fluteau, F., ... & Han, W. (2022). Reorganization of Asian climate in relation to Tibetan Plateau uplift. Nature Reviews Earth & Environment, 3(10), 684-700.
10 https://www.downtoearth.org.in/climate-change/did-southwest-monsoon-moisture-cross-the-himalayas-and-reach-the-tibetan-plateau-in-2025

These anthropogenic drivers of climate change give the signal for more erratic South Asian monsoon in the future. The key driving factors for these shifts includes; horizontal expansion of irrigated agriculture, urbanization of mountain valleys (heat islands), and deforestation and land use change.

Riverine flooding along Pakistan's eastern rivers, the Sutlej and Ravi, has intensified in recent years. This is a result of climate change combined with shifts in India's reservoir management practices. For instance, data from the Indian Meteorological Department shows that rainfall in August 2025 exceeded normal levels by 74%, with districts like Pathankot and Gurdaspur recording increases of up to 181%.

The 2023 Sutlej floods and the 2025 Ravi–Beas–Sutlej floods highlight how extreme rainfall in Himachal Pradesh and Indian Punjab, coupled with sudden reservoir releases, can drive massive floodwaters into Pakistan. The critical issue is that upstream storage facilities (including the Bhakra, Pong, and Ranjit Sagar dams) operate under Standard Operating Procedures (SOPs) focused primarily on optimizing irrigation, not on mandated flood control. Consequently, when these reservoirs reach maximum capacity, they automatically release excess water, exacerbating the flood situation downstream.

The risk of floods is heightened because downstream communities, forgetting the historical flooding of these rivers over the past decades, have encroached upon the river floodplains and even floodways. This encroachment, primarily for agriculture and temporary to permanent settlements, often involves the construction of farmers' bunds, which increases flood exposure. This situation is further complicated by the future prospect of reduced reservoir storage due to sedimentation, necessitating increased spillway releases during intense monsoon peaks.

To combat these human-driven disruptions, Pakistan must critically rethink its development trajectory rather than only claiming climate reparations. A growth model centered on horizontal land enclosures, water-intensive high-delta crops, unregulated urban expansion, and the replacement of natural vegetation with heat-absorbing building infrastructure is no longer sustainable in a rapidly warming climate.

Given the increasing climate variability and altered hydrological behavior of the eastern rivers, Pakistan needs to reconsider and revise its downstream flood-management strategy.

Pakistan must adapt and redesign its agro-ecological crop zoning to match ecological realities, improve bilateral real-time data sharing for eastern rivers with India, promote climate-sensitive land use in mountain regions, restore forests and watersheds, and encourage urban development that utilizes climate-friendly building materials and designs.

Only by aligning our economic choices with environmental limits can we mitigate the escalating hydrological risks and protect vulnerable communities across the Indus Basin. Without these measures, the aging upstream storages and intensifying monsoon dynamics will continue to deliver more frequent and severe floods to Pakistan's flood plains.

## Colonial and Post-Colonial Development and Changing River Morphology

To better understand the connection between colonial and post-colonial development and river morphology, one must understand the socio-hydrology of the pre-colonial period.[11] The pre-colonial integrated agriculture growth model was layered into four distinct types of livelihood and economic activities that were deeply synchronized with the natural cycle of the river flows (up and down stream) and its seasonal behavior.

- The first layer of the community was engaged with fishing and inter-river trade, depending heavily on the natural connectivity between rivers, wetlands, and seasonal channels. Their livelihoods were tied to the mobility offered by rivers, which acted as transportation corridors.

- The second layer of community settlements engaged in small-scale subsistence farming and animal husbandry, relying on the fertile alluvial soils deposited by recurring floods. Their production system was low-input but resilient, embedded within the seasonal rise and fall of the river water.

- The third layer of community settlements lived in scattered places where availability of fresh groundwater assisted agriculture activities through deep well irrigation. These settlements were slightly away from the main floodplains, where river recharge enabled deep wells to produce reliable annual yield.

- The fourth layer of community temporary settlements practiced pastoralism assisted by rainfall and rain-collection ponds during the monsoons; their mobility dependent on the grazing cycles shaped by monsoon patterns.

As the river level rose in the monsoon season and spilled out into the floodplain, people temporarily moved upward into the Bar[12] areas, relatively higher elevation terraces offering natural protection. After the flood water eventually receded, communities returned and resumed agriculture, benefiting from the freshly deposited alluvium and replenished fertile and moist soil. Historically, communities deliberately chose naturally armoured fill terraces for permanent settlement, often located above elevated "donut-shaped" geomorphic formations that provide greater stability against riverbank erosion.

Historical evidence, both archival and oral, indicates that these societies did experience floods. However, these events were managed through an evolutionary

11 Di Baldassarre, G., Viglione, A., Carr, G., Kuil, L., Salinas, J. L., and Blöschl, G.: Socio-hydrology: conceptualising human-flood interactions, Hydrol. Earth Syst. Sci., 17, 3295–3303, https://doi.org/10.5194/hess-17-3295-2013, 2013

12 Bar is a local term for the raised land between the two rivers. This geographic term also shaped the identity of the community and people identity themselves with these terms i.e., Bar and Hathar

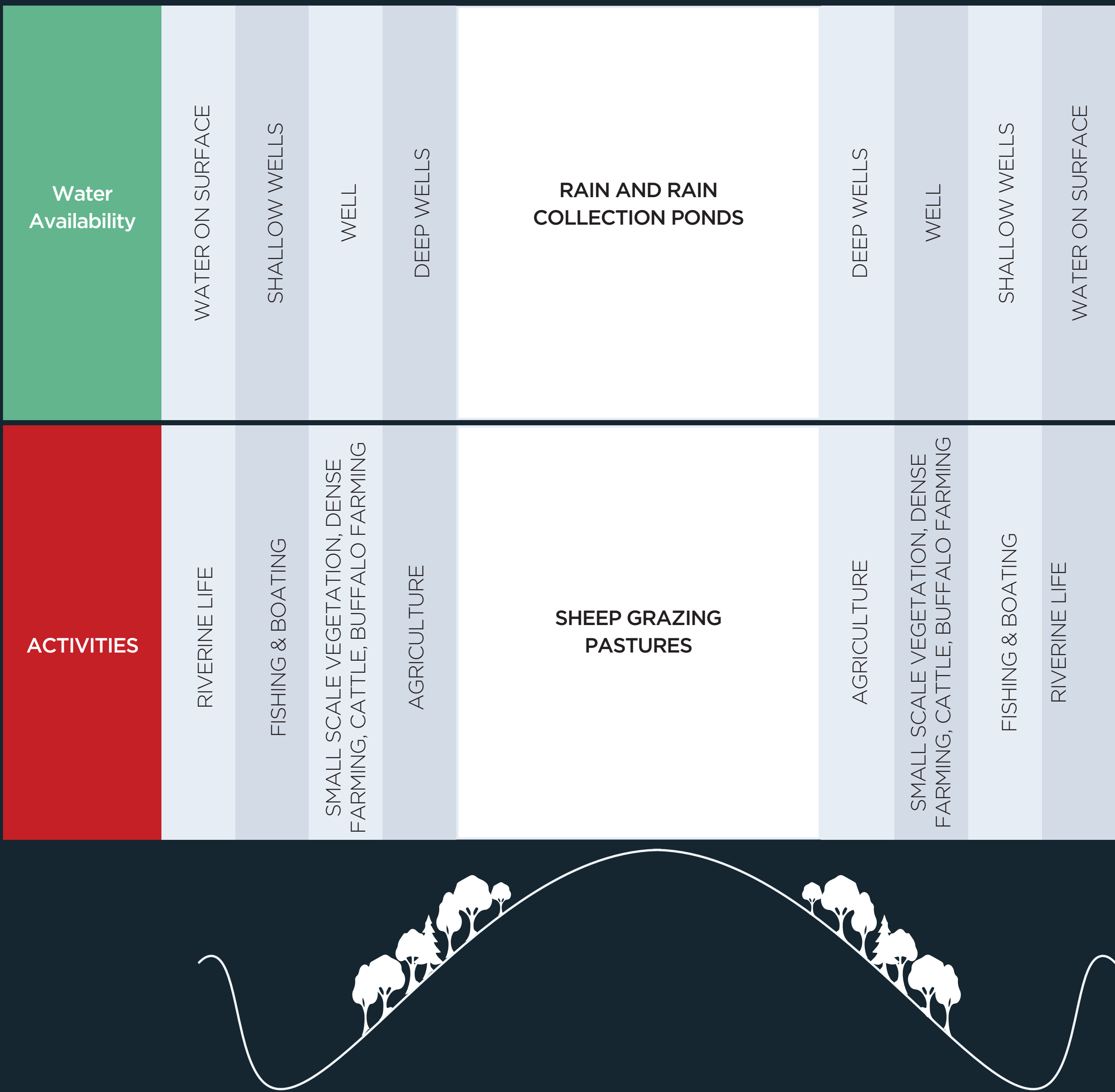


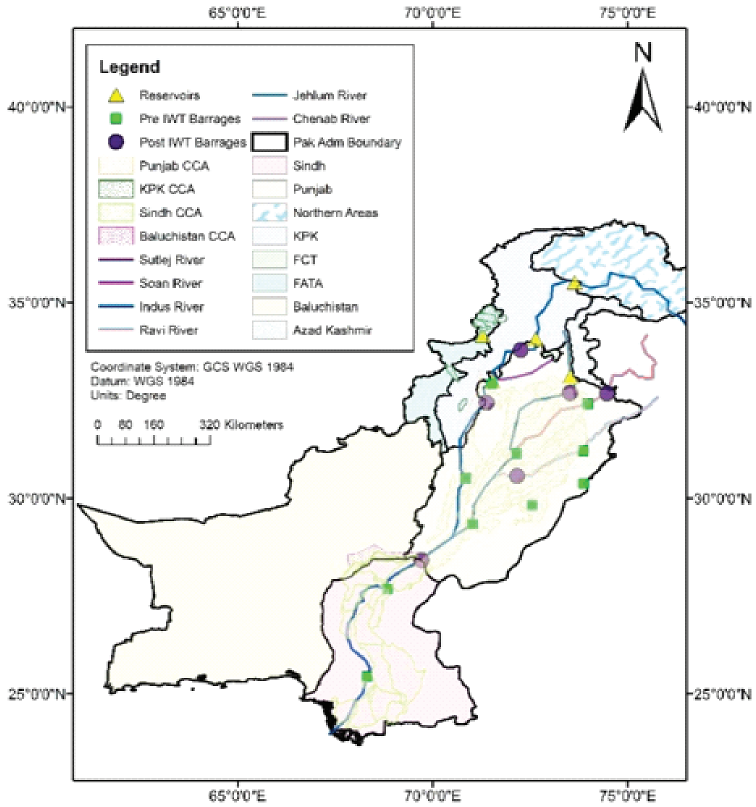

Figure: Conceptual Layout of Socio-Hydrology Between the Doab's[13]

process. In years of exceptional flooding, rivers naturally meandered, shifting their major and minor floodways. When this occurred, communities historically relocated, abandoning older settlements to establish new ones. Although disruptive, this process was aligned with the gradual pace of geomorphic change, as the river's meandering was slow, not sudden.

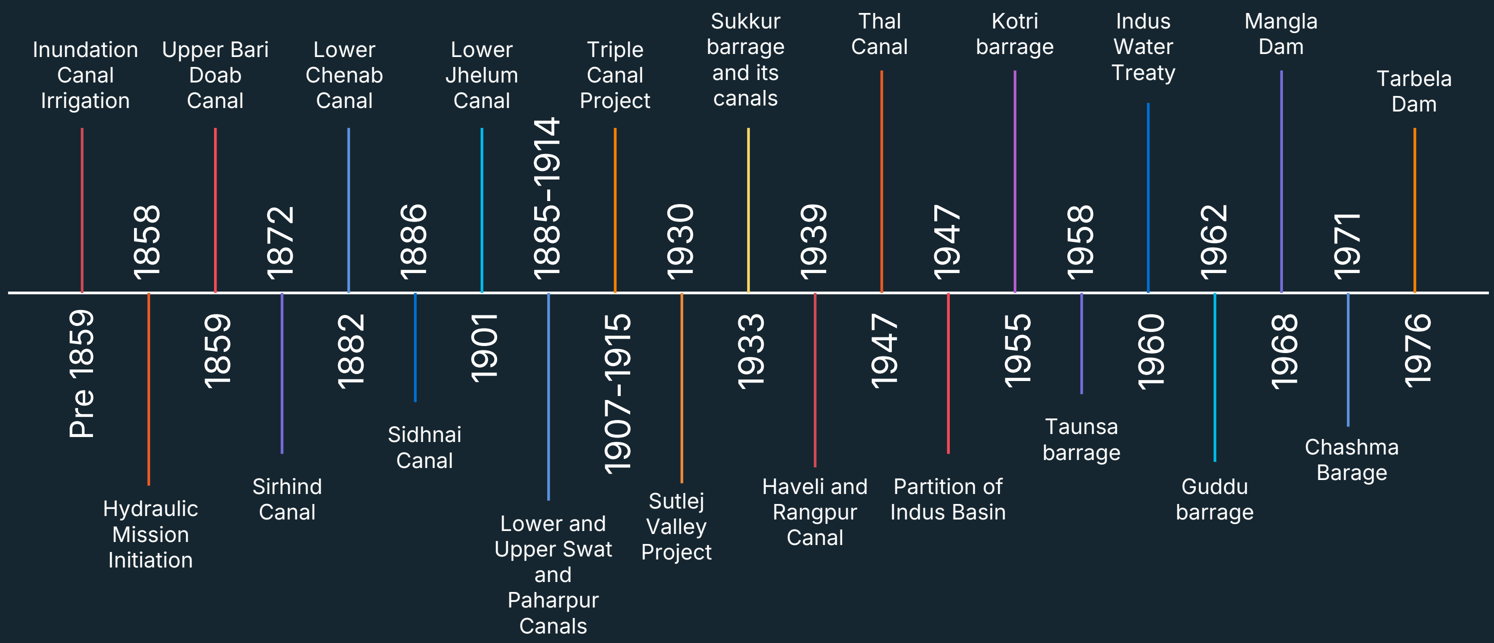
However, after the annexation of Punjab, this growth model was fundamentally changed. The canal-colonization and hydraulic mission introduced a new political economy of land enclosures and engineered land and waterscapes.[14] At the time of partition, the total canal command area was around 10.4 million hectares which expanded by 65%,after the partition covering approximately 17.2 million hectares. The British constructed over 62,000 kilometres of canals, and by the 1970s, after the Indus Waters Treaty (IWT), major dams and link canals were added to transfer water from the western rivers to the eastern canal systems.[15] This created a new west-to-south-east hydraulic network that further reduced the possibility of natural river dynamics and choked long-established geomorphic patterns.

In today's terms, this colonial and post-colonial hydraulic infrastructure represents an investment of roughly US$300 billion.[16]

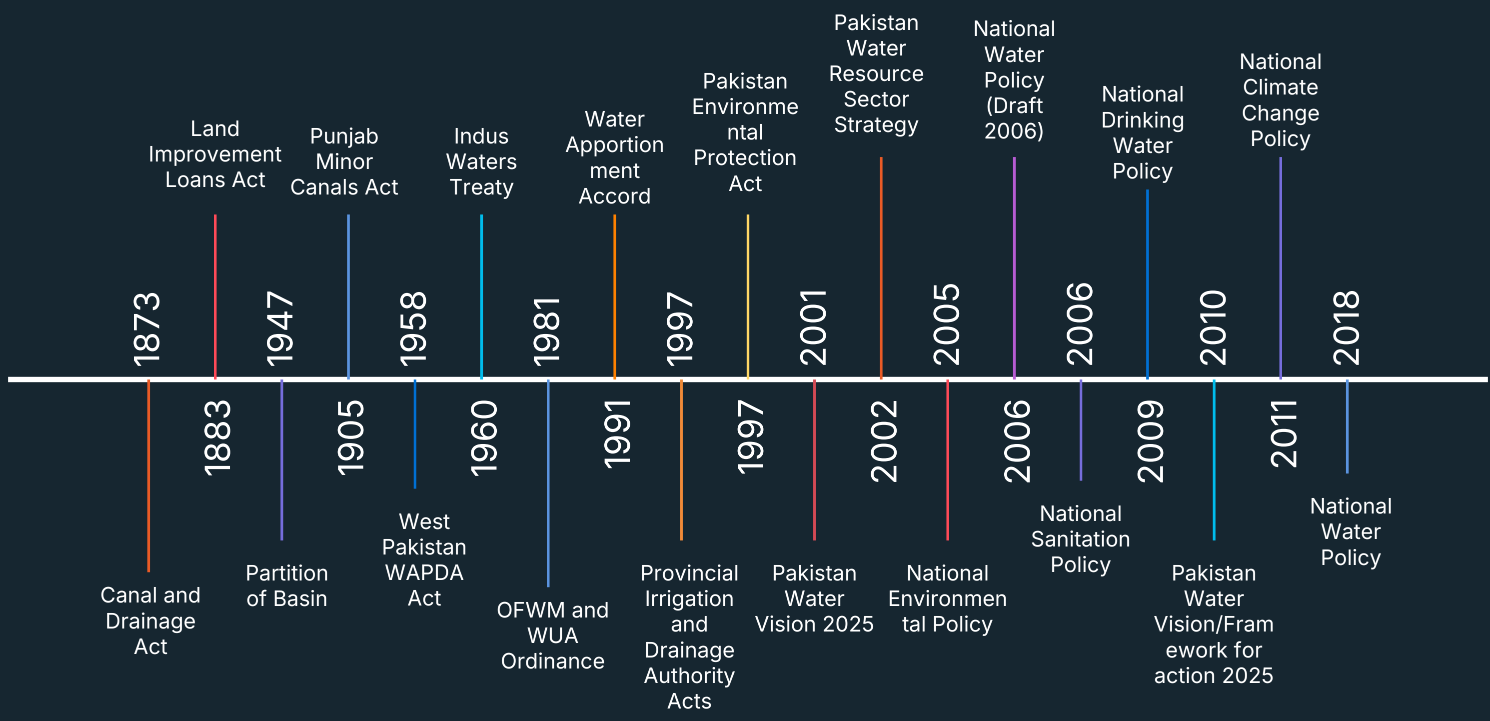
13 Authors own Illustration based on the interviews with riverine communities
14 Aijaz, A., & Akhter, M. (2020). From building dams to fetching water: Scales of politicization in the Indus Basin. Water, 12(5), 1351.
15 Akhtar, S. (2019). Water sharing conflicts and management in the Indus River Basin. J Aqua Sci Oceanography, 1, 202.
16 Young, W. J., Anwar, A., Bhatti, T., Borgomeo, E., & Davies, S. (2019). Pakistan: getting more from water.




Figure(a) Physical locations of major infrastructure in Pakistan




Figure(b) chronology of physical infrastructure intervention in the Indus Basin




Figure(c) chronology of soft intervention (laws and ordinances) in the Indus Basin[17]

Following large-scale land enclosures, new settlements began to emerge inside the floodplains and on adjacent terrestrial areas that were historically avoided due to flood risk. To protect the newly expanded canal command area from flooding—and to ensure that the river passed through barrages and headworks from where canals diverted water into distant regions—engineers began constructing a rigid system of embankments and channelized river reaches.

Through these river training works, rivers are forced to flow through designated sections, minimizing much of the natural meandering state. Over time, this reduced the river's ability to spread and deposit sediment across the floodplain, which resulted in sedimentation raising the riverbed higher than the surrounding land, creating stretches of what hydrologists call a suspended river.[18]

Today, in the Indus river basin, there is a continuous struggle between the raised riverbed and the flood embankments built to confine it, as these attempt to protect both expanding urban settlements and the canal command area. All the colonial and post-colonial infrastructure development has taken place under this overarching flood-control strategy. As a result, some cities and urban centers—such as Jhang, which sits directly on the bed of the Chenab River—are now locked into high-risk positions created by this inherited hydraulic configuration.

## Colonial and Post-Colonial Development and Changing River Morphology

With the expansion of large irrigation systems and engineered water infrastructure, river channelization emerged as the dominant flood control strategy in Pakistan. As irrigation networks, barrages, and headworks expanded, the need to confine rivers into fixed, predictable corridors grew significantly. In this context, various flood protection structures—bunds, levees, spurs, studs, and embankments—evolved alongside the major irrigation structures to protect the newly settled canal command areas and nearby population clusters.[19]

Flood bunds, usually constructed with earthwork, became essential works, designed to contain river spills within a constrained channel and protect settlements located beyond the flood embankments. Over time, a complex system of flood protection and river-training works developed along the Indus River and its tributaries. These structures provide protection against high-magnitude floods and also serve to control riverbank erosion in inherently unstable, highly erodible lithological formations, where river channels frequently

17 Arfan, M., Ansari, K., Ullah, A., Hassan, D., Siyal, A. A., & Jia, S. (2020). Agenda Setting in Water and IWRM: Discourse Analysis of Water Policy Debate in Pakistan. Water, 12(6), 1656. https://doi.org/10.3390/w12061656
18 Li, X., Zhong, D., Zhang, Y. J., Wang, Y., Wang, Y., & Zhang, H. (2018). Wide river or narrow river: Future river training strategy for Lower Yellow River under global change. International Journal of Sediment Research, 33(3), 271-284.
19 National Flood Protection Plan-IV, 2015

alter their flow paths. Areas of the floodplain once considered safe can become unsafe as the river migrates, thereby generating continuous demand for new or strengthened flood protection works.

## Institutionalization of the Channelization Approach

To manage this expanding infrastructure, the Federal Flood Commission (FFC) was established as the federal institution responsible for planning, executing, and monitoring flood protection measures across the country. Over multiple time periods, from 1978 to 2015, various structural flood protection projects received allocations through the FFC. From 1978 to 2015, the FFC completed 10,591.25 million rupees worth of schemes, including the construction and strengthening of flood embankments, causeways, spurs, gabions, and other protective works.

Under the National Flood Protection Plan-IV (NFPP-IV), an additional 90,992 million rupees were proposed for structural measures, with 13,332 million rupees allocated to non-structural measures such as hydrological studies, early warning improvements, and research on river behavior. This financial and institutional commitment further entrenched channelization and embankment-based flood protection as the core national strategy. This has been a very high cost strategy and has put a heavy financial burden on the national exchequer.

## Operational Challenges and Embankment Vulnerabilities

Despite this extensive and high cost system, embankments still remain vulnerable due to design limitations, inadequate maintenance, and natural geomorphic processes. Surface erosion of embankments often results from rodent burrows, poor maintenance, and the deterioration of wetted channels, while subsurface failures invariably trigger breaches under high flood pressures. Major breaches during the 2010 flood—including those at Taunsa Barrage, Jampur Flood Bund, and two breaches at Jinnah Barrage in Punjab, along with breaches at Guddu Barrage and Tori Bund in Sindh—are examples of failure events, some of which can be categorized as natural breaches due to extreme hydraulic stress.

## Design Inconsistencies and Non-Uniform Safety Margins

Flood protection works across Pakistan are designed using non-uniform hydrologic, hydraulic, structural, and geotechnical parameters.[20] This results in varying and inconsistent factors of safety across embankments and river-training structures. For example, freeboard heights above the design High Flood Level (HFL) differ significantly between sections of the Indus and its major tributaries, reflecting the absence of a uniform national design standard.[21] These inconsistencies, when combined with geomorphic instability and maintenance challenges, further undermine the reliability of the channelization-based flood protection system.

## Impact of Private Bunds in Floodplain and Highways/Motorways

Complicating matters further is the unregulated construction of private bunds, often built to reclaim agricultural land. These private structures have narrowed the river corridor, significantly reducing its natural conveyance capacity in many reaches. This reduction increases hydraulic pressure on official embankments—one of the key factors behind the catastrophic failure at Tori Bund in 2010. As the natural accretion raised the riverbed above the natural surface level (NSL) in multiple locations, the Indus River increasingly behaves like a suspended river. Since the 1940s, the bund systems and barrages have controlled inundation but have simultaneously produced higher peak flows during major flood events. Once water escapes the bund system, it often cannot return to the river, leaving vast parts of Sindh highly vulnerable to prolonged flooding and stagnant water which severely damages the agricultural land.

The post-2000 era has introduced another, more insidious layer of obstruction: linear mega-infrastructure such as highways and motorways; which inadvertently function as unintended levees dissecting the floodplains. These embankments are typically elevated and contain insufficient culverts or cross-drainage structures. As a result, they act as impermeable barriers that disrupt the natural sheet-flow across floodplains.

The 2014 and 2025 floods exposed this development-induced and infrastructure-led crisis along the M-2 section of the Motorway and functioned as a massive hydrological barrier. One side of the motorway experienced severe flooding with rising water levels, while the opposite side remained entirely dry. This discrepancy reveals how the motorway split the natural floodplain into two disconnected compartments. Without adequate cross-drainage structures, the floodplain lost its ability to equalize pressure, leading to prolonged waterlogging in agricultural lands and settlements trapped on the inundated side.

In 2025 the lower Chenab, M-5 section of the motorway in south Punjab, severely choked the historical overflow paths of both the Chenab and Sutlej rivers.[22] The motorway's raised embankment obstructed the natural

20 Zakir-Hassan, G., Hassan, A., & Shabir, G. (2022). Evaluation of impact of soil properties on strength of flood levees in Indus River Basin of Pakistan. Australian Journal of Engineering and Innovative Technology, 4(3), 52-64.
21 https://www.thefridaytimes.com/23-Aug-2025/how-pakistan-s-2022-floods-exposed-corruption-and-incompetence
22 https://www.app.com.pk/domestic/punjabs-road-network-in-ruins-as-floods-keep-m-5-motorway-closed-for-15 days/#:~:text=The%20PDMA%20report%20noted%20that,before%20conditions%20return%20to%20normal.

conveyance capacity of the river, leading to a buildup of water pressure against the embankment system. This redirected the river flow, laterally, toward vulnerable points, making Tehsil Jalalpur Piruwal, already located in a sensitive hydraulic pocket, far more exposed to inundation. Instead of dissipating across the floodplain, floodwaters were forced into confined compartments, intensifying flood damage.

## Structural and Institutional Non-Compliance

A critical underlying issue, creating development induced floods, is the bureaucratic fragmentation that prevents hydrologically informed planning. The National Highway Authority (NHA) builds motorways largely through engineering-construction norms, while the FFC, Irrigation Departments, and provincial disaster authorities are responsible for river morphology and flood behavior. However, there is no mandatory integrated hydrologic review for any major highway construction and the National Highway Authority rarely complies with FFC or floodplain zoning recommendations for its projects. Thus the result of this isolated planning results is that:

- Cross-drainage structures are minimized to reduce construction costs.
- Hydrological modeling is outdated or omitted entirely.
- FFC recommendations are taken as procedural rather than operational.
- Irrigation Departments lack authority to enforce floodplain protection against national infrastructure projects and the
- Environmental Impact Assessments (EIAs) treat floodplain hydrology superficially.

Designing critical infrastructure like highways, motorways, private bunds, irrigation systems, and flood embankments in isolation leads to institutional silos. This fragmentation, in turn, fractures the floodplain into separate compartments, disrupting its natural hydrological integration and has caused the major disruption of river water during floods.

## The Chenab Flood 2025 and Barrage Operation Failures

The 2025 flood of the Chenab River was historically significant, in numeric terms, based on its flood volume data. The flood wave began with intense, widespread rainfall across the Chenab River catchment in the Jammu region. The rising waters from smaller tributaries, including the Tawi River and numerous smaller streams (nallah's), initially flooded adjacent towns. These smaller water bodies then converged with the main Chenab River, significantly amplifying the flood wave downstream.

The Marala Barrage and Head Works, the first upstream infrastructure on the Chenab River, was commissioned in 1968, replacing the earlier 1912 weir. It was designed to handle the flow of up to 1.1 million cusecs of water. The Marala barrage effectively managed the peak flow of 895,740 cusecs that arrived in the early morning of August 27, 2025. Crucially, the barrage successfully regulated this major flood peak downstream without requiring any emergency breaching operations.

Downstream, the next barrage, Khanki, received an even bigger peak of 1,085,750 cusecs, after receiving additional runoff water from small streams entering the Chenab between Marala and Khanki barrage.

The second barrage, Khanki barrage, also successfully conveyed the flood peak in Chanab and directed the flow downstream towards the third barrage, i.e. Qadirabad Barrage. However, the flood situation worsened as Qadirabad Barrage's design capacity, falling between 800,000 - 900,000 cusecs, was below the approaching flood peak volume of more than a million cusecs.

The situation was described as a 'crisis moment' by a technical expert at the National Disaster Management Authority. They noted that in case of the barrage's collapse, the flood water could have washed away the homes of over 2.8 million people. As it happened, the Punjab Irrigation Department was able to skillfully operate the barrage gates and successfully managed the flow of 996,030 cusecs of water, which was almost 100,000 cusecs above the designed capacity of Qadirabad barrage. The excess water was diverted through the breaching sections, which helped in reducing the peak before it could travel further downstream.

The fourth barrage on Chenab which is two hundred and six kilometers from Qadirabad barrage is the Trimmu barrage, situated near district Jhang. With the reduced flood peak at Qadirabad Barrage, it was expected that Trimmu Barrage which had been recently upgraded under the ADB barrage rehabilitation program—would easily receive and allow flows within its supposed enhanced design capacity of 819,201 cusecs, compared to its original design capacity of 650,000 cusec.[23]

However, instead of smoothly transmitting the flood wave, the situation deteriorated. Flood routing analysis revealed that the peak observed at Qadirabad did not propagate downstream to Trimmu with the expected lag time of 48 hours. Meanwhile, the gauge at the Rivaz Railway Bridge, located approximately 30-35 kilometers upstream of Trimmu Barrage, recorded maximum flood levels. The Punjab Irrigation Department relies on this gauge to determine emergency operational decisions, including the activation of breaching sections. To prevent the inundation of Jhang City, the Rivaz Bridge flood bund

23 https://www.adb.org/sites/default/files/project-documents//47235-001-pam.pdf

was deliberately breached on 29th August 2025. [24]This operation helped divert 100,000 to 150,000 cusecs of water. Subsequently, controlled breaches were also executed at the Athara Hazari dyke in Jhang District and along the Right Marginal Bund of the Trimmu headworks. Despite the barrage's upgraded capacity, instead of receiving a comparable routed peak (adjusted for normal channel losses and travel time), Trimmu recorded a maximum discharge of only 550,965 cusecs on 1 September 2025.[25]

This raised an intriguing technical question: Why was Trimmu unable to pass volume according to its upgraded design capacity? The project administration document prepared by the Asian Development Bank (ADB) clearly describes the changing hydrologic and climate conditions as a rationale for an increased design capacity for the Trimmu and Panjand Barrages. However, so-called upgradation failed to function as an improved regulatory capacity of 819,201 cusecs.

The 2025 floods actually demonstrated the reduced capacity of Trimmu barrage, clearly due to a design failure or inadequate river training works, sedimentation or operational constraints. This reduced flood-carrying capacity at Trimmu, created a significant backwater pressure on upstream flood embankments. Under this stress hydraulic condition, the Punjab Irrigation Department was compelled to do the controlled breach of flood embankment in order to protect the adjoining Jhang City from a potentially catastrophic embankment breach in the barrage.

In conclusion, the Trimmu barrage was unable to manage this extreme flood wave—either because of a design flaw or insufficient upstream river-training works—leaving controlled breaching as the sole practical option for reducing risk.

Downstream Trimmu, the next structure is Panjnad Barrage, originally commissioned in 1929 and re-commissioned in 1931, which has a design discharge capacity of 699,320 cusecs. It was also remodeled under the same ADB program to have the upgraded capacity to pass the 100-year flood of 864,183 cusecs. Again, due to flawed design or ineffective upstream river-training works, Panjnad was unable to regulate this enhanced design and could only pass 703,698 cusecs on 11 September 2025. This choking created immense pressure on the upstream embankments, making additional controlled breaches unavoidable. Consequently, several small towns, such as Jalalpur Piruwal and Ali Pur were inundated and experienced extreme flooding.

The ADB's $700 million Multi-Tranche Financing Facility (MFF) 2007–2017 for the Punjab Irrigated Agriculture Investment Program had promised that upgrading these barrages and increasing their flood capacity would reduce flood risk for 150,000 people cumulatively. But as it turned out poor implementation and weak institutional capacity enhanced the infrastructural induced flooding for 0.92 million people of the Muzaffargarh district—located between Trimmu and Panjnad barrages.

The UN-OCHA's Rapid Needs Assessment (RNA) report, published on September 23 and covering 18 affected districts, indicated that 4.2 million people in Punjab were impacted by the floods. A striking 64% of the displaced population, over 3 million people, were concentrated in just five of the twenty eight flood-affected districts. Muzaffargarh was the most severely affected district, accounting for 33.6% (0.92 million) of the total displaced population. The other heavily impacted districts included Jhang (14%), Bahawalpur (13%), Khanewal (11.5%), and Multan (10%). Consequently, the report identified Muzaffargarh, Jhang, Bahawalnagar, and Khanewal as the top four most vulnerable hotspots.

Muzaffargarh has historically been highly susceptible to floods. Since the major 'super floods' of 1992, the district has experienced three major flood disasters and four smaller events. Notably, Muzaffargarh incurred the highest share of losses in Punjab during both the 2010 and the more recent 2025 floods.

## Anti-Thesis of Channelization: 'Let the River Flow'

Against this backdrop, civil society and environmental activists have raised critical questions about the ill-planned and flawed flood management strategies that remained dominant in the Indus Basin during the last 150 years. Their critique became louder especially after each major flood event, and many proposed an alternative pathway summarized in the shape of slogan 'Let the River Flow'.This discourse is more popular in the Lower Indus Basin, particularly in Sindh, where communities view upstream water infrastructure, large dams, diversions, link canals, as threats to their water rights and downstream flows.

However, most proponents of this discourse rarely unpack what 'Let the River Flow' actually entails in practical hydrological, agrarian, and political-economic terms. Their framing tends to limit the interpretation of this slogan to 'No More Dams on the Indus River'. This narrow interpretation ignores the broader floodplain hydrology and completely sideline the root cause of the problem which is the existence of river channelization infrastructure to sustain the canal command areas. And this channelization is not even limited to Punjab as Sindh is also part of the same colonial hydraulic regime. Thus, the idea of "freely flowing river" has become a leverage point to claim more water and has been reduced to a resource-nationalist claim, which is common among lower-riparian activist groups worldwide, especially where inter and intrastate water disputes shape political identity.

Implementing a profoundly different approach, such as 'Let the River Flow' or 'Living with Floods', faces significant, deeply rooted challenges. These constraints

24 https://www.dawn.com/news/1938435/all-embankments-along-chenab-secure-jhang-district-administration#:~:text=The%20Jhang%20district%20administration%20has%20stated%20that, and%20the%20Trimmu%20Barrage%2C%E2%80%9D%20the%20spokesperson%20said.
25 https://ffd.pmd.gov.pk

stem from a confluence of factors, including colonial path dependency and technological and economic lock-in, which collectively restrict the potential for realistic change in the short- and medium-term.

Path dependency means that once a society takes a particular route, be it technological, institutional or economic, it becomes extremely difficult to reverse it, even when the original conditions have changed. Whereas, technological lock-in refers to situations where an existing technology becomes so embedded that shifting to a new technology becomes prohibitively costly.

During the last two centuries, the hydraulic bureaucracy established canal colonies, settled millions of people in newly irrigated lands. Entire new cities and many old towns expanded horizontally around canal networks. These settlement patterns locked populations into floodplains and canal command areas, making large-scale seasonal flooding, socially and politically impossible without massive resettlement and relocation. Over time, rural economies became dependent on barrage-regulated irrigation, not natural floods. As this cropping pattern stabilized, farmers locked into it. Thus, seasonal inundation would damage these crops, making "let the river flow" proposal appear utopian rather than feasible under current agrarian political economy.

Moreover, allowing the river to flood these areas seasonally would require relocating industries, altering crops, and redesigning irrigation regimes. Such a transition was technically complex and economically disruptive in the shorter and medium term for sure. However, the slogan remains powerful as a critique but weak as a policy blueprint because without dismantling the underlying lock-ins—technological, institutional, agrarian, and economic—the radical re-imagining of flood management will remain aspirational rather than actionable. The challenge is not ideological opposition but the material reality that millions of people, billions of dollars in infrastructure, and entire economic sectors depend on the current regime. Thus, any genuine vision of "Let the River Flow" must grapple with the structural roots of path dependency that shape the Indus Basin's future, not just oppose new dams but rethink the entire colonial hydraulic architecture.

## A Praxis Between 'Channelization' and 'Let the River Flow': Room for the River

The debate between channelization and 'Let the River Flow' is often framed as a binary choice, but historical experiences—especially from civilizations that lived for millennia with sediment-heavy rivers—demonstrate that flood management requires a synthesis rather than an ideological stance. The most convincing parallel comes from the Yellow River Basin in China, where a 2,000-years old debate continued between the two camps; those who believed in keeping the river strictly confined through embankments, and those who advocated for the wider river flood corridors to spread, deposit sediment, and dissipate energy of the flood wave.[26]

The Yellow River Basin, similar to the Indus, is a river that carries a heavy sediment load, constantly changes its course, builds up its bed, frequently breaches its embankments, and consequently reshapes the geography of the area. For centuries, Chinese hydrologists debated whether the river should be tightly "controlled and disciplined" or allowed 'room to meander'. The record shows that periods of extreme channelization often led to catastrophic levee failures, while periods of strategic openness such as creating designated floodways, bypass channels, and seasonal retention zones, reduced the destructive pressures on embankments. This long historical discourse provides valuable insight for today's Indus Basin flood control strategy, where the conflict between colonial hydraulic engineering and a renewed ecological counter-narrative 'Let the River Flow' mirrors the ancient Chinese debate. However, the way forward lies neither in abandoning channelization altogether nor in a romanticized return to pre-colonial riverine regime, but crafting a praxis with a set of practical, hybrid strategies by integrating engineered control with ecological space.

As we demonstrate in the previous section that the Indus and its tributaries, much like the Yellow River Basin, behaves as a suspended river in multiple river reaches, with its bed higher than the surrounding floodplain due to a century of embankment confinement and sediment deposition. The Chinese experience demonstrates that the more you constrain a sediment-laden river, the more catastrophic the breaches become, because; sediment has no place to spread, riverbed rises faster, and consequences of failure become unmanageable. Thus, this escalation trap historically led hydrologists to conclude that pure channelization guarantees short term relief and eventually worse disaster. The synthesis between the two extremes is found in the pragmatic philosophy of 'Room for the River'; which acknowledges the value of engineered protection but accepts the river's need for hydrological and geomorphological space. The Yellow River Basin successfully implements a hybrid flood management strategy that incorporates "flood corridors." This approach allows for natural river meandering and sediment deposition during peak flows, while dedicated storage facilities regulate flood peaks and manage sediment. Since the 1960s, this strategy has proven effective, preventing mega-catastrophic floods on the scale of those in 1887 or 1931. Furthermore, controlled silt flushing operations have dramatically reduced the risk of the river bed rising and significantly lowered the frequency of major floods, resulting primarily in localized events rather than basin-wide disasters.

26 Wang, Z., & Liu, C. (2019). Two-thousand years of debates and practices of Yellow River training strategies. International journal of sediment research, 34(1), 73-83.

## Conclusion and Recommendations

There is a need to translate this praxis to the Indus Basin by designating flood corridors and depressions as identified in the Pakistan Water Dialogue report in 2015. A 'Room for the River' strategy in Pakistan must combine four elements:

- Designated flood corridors and depressions at lower value lands like the Cholistan and Thar deserts and old paleochannels of the river Beas and Sutlej for controlled flooding. Such corridors and depressions also need to be identified for the western rivers including the Indus River. The old paleochannels of the Indus and Hakro river bed can be used in Sindh for such purposes.

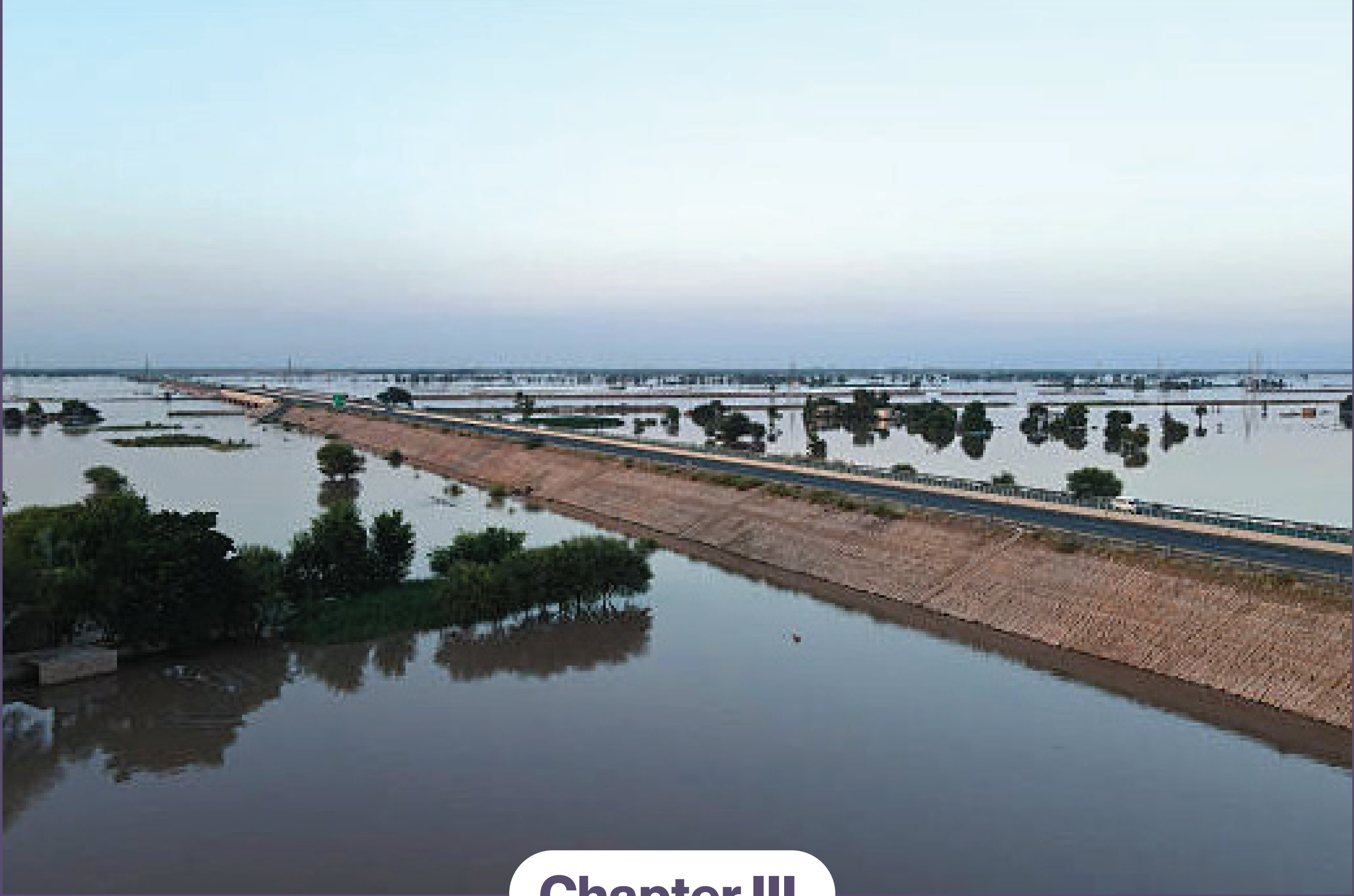
- Need to designate the retention basin for the Jhelum and Chenab River flooding to reduce the pressure at the embankments.

- Instead of the impossible task of raising embankments universally, the focus should be on prioritizing their construction where socio-economic density necessitates protection, such as around major towns, industrial areas, and critical infrastructure. In contrast, rural settlements should be protected using "donut-type" embankments that allow floodwater to pass through.

- Correcting design flaws of the existing bottlenecks at all highways, motorways which obstruct the passage of flood water with natural flood water drainage flow patterns and private bunds.These corrective design interventions would restore natural connectivity of the floodplain without eliminating infrastructure.

- All future infrastructure planning and designing must pass through comprehensive hydrology.
Flood peak regulation and sediment management strategies must be adopted as a strategy to maintain the downstream conveyance capacity of the river channel.

Integrating engineering with river morphology and ecology, is the only sustainable solution for effective flood management in the Indus Basin.



Chapter III

# BUILDING INSTITUTIONAL RESILIENCE

Noreen Haider

## Introduction

Pakistan has, for several years, faced increasingly severe hydrometeorological hazards, resulting in recurrent economic losses amounting to billions of dollars annually and posing significant threats to national security and socioeconomic stability. Paradoxically, these escalating disasters persist despite the presence of an extensive institutional landscape comprising numerous authorities, commissions, ministries, departments, and specialised councils ostensibly tasked with disaster mitigation and management. The persistence of large-scale destruction because of floods, raises critical questions about the efficacy, coordination, and operational capacity of these bodies; why have they been unable to prevent or even meaningfully lessen the destruction caused by recurrent flooding and why does each successive event reveal new layers of institutional inadequacy? This chapter examines the governance architecture of flood prevention and control at both federal and provincial levels, analyses the mandates and operational roles of the responsible institutions, assesses the existing physical and administrative flood-management infrastructure, and identifies the systemic factors underpinning their limited effectiveness.

## Evolution of National Flood Protection Plans (NFPPs):

Since the establishment of the Federal Flood Commission (FFC) in 1977, Pakistan has launched a series of flood protection and restoration programs. Three 10-year "National Flood Protection Plans" (NFPP) have been prepared and executed, NFPP-I (1978-1988) NFPP-II (1988-1998)[1] and NFPP-III (1998-2008).[2] A fourth plan, NFPP-IV (2015-2025)[3] was also prepared and approved by the Council of Common Interests in May 2017, for implementation but it has not been fully implemented and was stalled for lack of funds. It was only after the catastrophic 2022 floods that the NFPP-IV was formally updated and re-prioritised. The updated plan contained hundreds of sub-projects (documents cited 375 sub-projects and thousands of schemes in the updated NFPP-IV and earlier technical summaries refer to several hundred individual embankment/scheme items (one list mentions 582 embankment schemes in some formulations) The updated NFPP-IV (the version most frequently cited since 2022) shifts toward an Integrated Flood Risk Management approach and lists about 375 sub-projects with an estimated cost (reports cite ~PKR 825 billion).[4 5]

NFPP-IV was never fully financed/rolled out as a single umbrella PC-I in 2017and the implementation remained fragmented across federal and provincial programmes and various PSDP/FPSP packages. Hundreds of schemes remained outstanding against a much smaller number completed up to June 2023 in the climate/disaster audit.

Since 2023–2024 several initiatives and donor-supported programmes (ADB, World Bank, Climate Finance proposals, NDRMF/NDRMF-linked projects) have been working to prioritise and finance NFPP-IV sub-projects (including a proposed Flood Protection Sector Project package). Progress reporting in 2024–25 shows planning, prioritisation and some project approvals, but large scale construction and completions remain ongoing work.[6]

The important thing to note is that the thrust of flood prevention and control in Pakistan, continues to be major repair and construction work at hundreds of sites along rivers and canals. There is no plan to adopt nature based solutions for prevention or adaptation for climate change that would not only mitigate the flood damage but cost a fraction of the total amount spent on continued construction and works.

There are gaps in policy and strategy, implementation and operations and the institutional structure of disaster management in Pakistan which needs to be improved,

## Gaps In the Policy and Strategy

Despite experiencing numerous major flood events over the past two decades, resulting in billions of dollars in losses, Pakistan's risk reduction strategy remains fundamentally unchanged. The ongoing ineffectiveness of the current approach stems from several factors, among which the most significant are:

### 1. Failed Strategy of Containing Rivers

All rivers naturally meander across the plains and leave the rich alluvium on the land which is invaluable for keeping the land fertile and maintaining a healthy eco-system. But in Pakistan the ongoing strategy remains to contain the rivers and keep them restricted inside the embankments. Resultantly the rivers, in the Indus basin, have been depositing the silt inside their beds for decades and the constant battle between the rising levels of river beds and the need to construct ever higher embankments has been continuing for decades. Elevated riverbeds significantly reduce the rivers' capacity, which is a major factor leading to overflow

1 ffc.gov.pk+2DIVA Portal+2
2 ffc.gov.pk+1
3 ffc.gov.pk+1
4 Scribd+1
5 https://ffc.gov.pk/national-flood-protection-plan-iv/
6 adb.org+1

during flood events.

### Engineering Floods

As the rivers come into high floods, the perpetual tug of war ensues between the river and the irrigation authorities for saving the critical infrastructure on the rivers and managing the flood's peak intensity. As the rising waters exert pressure on the barrages, the protective bunds and sometimes major roads are breached,using explosives, to release the pressure and reroute the flood flow. Following the flood the breached sections have to be repaired and reconstructed. It is yet unclear as to how this reactive and costly method has persisted and why no sustainable alternative has been adopted.

### Unrealistic Planning

There are extensive efforts made in developing plans that do not get implemented which is a serious waste of time and public resources. For instance, despite thousands of work hours contributed by officials across federal and provincial departments, the resulting National Flood Protection Plan IV proved to be largely unimplementable. There was neither the funds nor the capacity to implement thousands of infrastructure projects and sub-projects in the National Flood Protection Plan IV. Instead of nature based, low cost, implementable solutions, the focus remains on 'fighting floods' with more infrastructure and works, which proves to be a losing battle every single time.

The current approach to flood management—focused on containing rivers, rerouting floodwaters, and obstructing natural river flow with poorly planned infrastructure—is demonstrably ineffective and unsustainable. The only truly sustainable solution involves collaborating with rivers, which requires understanding and respecting their natural cycles and paths. Regrettably, this essential, nature-based approach is absent from both federal and provincial flood management plans.

## Gaps in Operations and Implementation:

Despite a massive annual operation designed to combat the floods, significant and persistent gaps in the approach lead to poor execution and delivery. The most important reasons for these serious deficiencies include: Serious lack of integration among the departments:

**1. The core objective of 'Integrated Flood Risk** Management' has not been realized in Pakistan. Federal and provincial disaster management bodies—including dozens of departments, ministries, councils, authorities, and commissions— operate in silos, without the necessary coherence. They lack the systems and structures required to ensure adherence to a unified strategy.

### 2. Overlapping Authorities

The underlying structural challenge for a coherent and unified strategy and its implementation, lies in Pakistan's federal architecture. Although the 18th Constitutional Amendment formally devolved a wide range of subjects—including irrigation and disaster management—to the provinces, yet the practical distribution of authority remains asymmetrical.

Several pivotal institutions with significant influence over water governance, disaster preparedness, and early warning systems continue to operate under federal jurisdiction. These include the Water and Power Development Authority, the National Disaster Management Authority (NDMA), the Federal Flood Commission, Pakistan Meteorological Department, SUPARCO and other federal bodies whose mandates critically shape provincial capacities and outcomes. There are also federal ministries of Agriculture and Food Security although these departments are provincial domains. These authorities mostly work independently or in parallel with the provincial departments frequently overlapping their jurisdiction.

For example the canals are under the authority of Provincial governments but the dams are under the authority of WAPDA which is a federal authority, roads are the domain of provincial government but the Highways come under the authority of NHA which is a federal authority. Similarly the Federal Ministry of Climate Change is the responsible authority for Pakistan's Nationally Determined Contributions given at UNFCCC but these commitments have to be implemented through the provinces who did not come up with the NDCs. These federal NDCs do not reflect anywhere in the provincial planning nor are these binding on the provinces. This disconnect exists in every department between the center and provinces and among the provinces also.

The overlapping of authority between the federal and provincial authorities creates friction between the federal and provincial government especially when the governments are being run by different political parties, hostile to each other.

None of the disaster management authorities or Ministry of Water Resources is headed by a renowned expert on disaster management or hydrology or any related subject. Neither are the chief ministers and cabinet members experts in floods or river management, yet ironically the flood plans in the provinces are made and approved by the chief ministers. Sometimes, during the flood event, critical decisions and emergency measures, such as breaching protective bunds are undertaken at the discretion of the provincial and district administration who lack the necessary subject expertise and any incorrect decision can worsen the situation.

### 3. Asymmetry in Provincial Policies

There is also asymmetry in policies when it comes to river water management of sometimes the same river passing through two different provinces. There are differences in regulations and law regarding urban development, encroachment etc from one province to another which makes it difficult to implement a unified strategy for disaster prevention and preparedness . For example in KPK there is a 'River Protection Act amended 2014' that states that if any infrastructure that is built on the banks of the river is damaged or demolished by the river, there would be no compensation paid for it by the government, rather a fine of up to Rs 500,000 would be imposed for illegal construction.The Ordinance prohibits "constructing any building or undertaking any developmental work within two hundred feet … beyond high-water limit" on either side of rivers or their tributaries.[7] It also defines a "Provincial Control Area" for land-use / zoning up to 1,500 feet from the riverbanks, where development must follow special zoning plans.

But in Punjab there is a Flood Plan act 2014 which allows for a special building code to be prescribed specifically for flood-plain construction. This means that buildings in these areas can be constructed but subject to stricter design standards to make them more resilient to flooding. Building without permission can lead to up to 30 days of imprisonment and a fine of up to PKR 200,000.

When it comes to construction within the flood plains of any river there should be a uniform law and same set of rules in all provinces so that it should be ascertained that all permanent construction within the flood plains is illegal. However, this is not the case presently.

## 4. Weak Enforcement on Encroachments of Rivers

Enforcement on the rivers remains a huge challenge, particularly in Punjab and KPK provinces despite existing regulations, leading to massive and unpunished land grabbing on all rivers flowing past various cities. Be it Swat or Kunhar in KPK, Ravi in Lahore, Chenab in Sialkot or Sutlej there are massive encroachments on river beds and in their flood plains. So much so that entire housing colonies have been constructed inside the flood plains of Ravi with government approvals. In fact the Punjab Government itself had set up a Ravi Urban Development Authority RUDA for massive construction along the Ravi river declaring it the new Lahore for tomorrow.

In 2025, after the heavy rainfalls in the catchment areas in Kashmir, Ravi river came into high flood after almost three decades and inundated large swaths of land around Lahore. The satellite imagery of the inundation, however, clearly showed that the river water did not extend outside of its historic flood plains; yet scores of housing societies were flooded by Ravi, causing a massive loss and damage to property. This proves that these housing societies were built inside the active flood zone of river Ravi. While the Punjab government asserts that these housing societies lacked proper official authorization, their construction in active flood zones occurred over many years, with numerous government departments failing to intervene and prevent it.

Housing societies in Lahore Raviflood 2025

## 5. Disconnect between the Nationally Determined Contributions NDCs and Provincial planning

After the 18th Constitutional amendment agriculture, water management, urban planning, disaster response, irrigation, land use, forestry, infrastructure development, and construction standard all have been devolved to the provincial level; these are precisely the domains where climate impacts manifest most acutely and where there is the need for adaptation. Yet, NDCs are made and presented by the Ministry of Climate Change at the Federal level. The provinces were neither mandated nor systematically supported to formulate their own NDCs and develop implementation frameworks. As a result NDCs remain completely decoupled from the provincial planning processes.

Both Nationally Determined Contributions NDCs in 2016 and 2021 articulated ambitions for climate-resilient agriculture, upgraded drainage systems, and strengthened disaster preparedness. However, whenever Pakistan is struck with an extreme hazard, it exposes the lack of capacity, long term preparedness and any real upgradation at the provincial level which would demonstrate better resilience as committed by NDCs.

7 Scribd+2KP Code+2

It is clear that the provinces are not driving any policy as envisioned by the NDCs nor adopting long term strategies for climate resilient agriculture which can withstand the erratic climate change impacts. In Sindh, for instance, the agriculture department has not been able to follow any strategies for introducing salt-tolerant crop varieties despite federal commitments to do so. The irrigation department had not undertaken climate-proofing of canal infrastructure or maintenance of spurs and bunds as they were committed to do according to the NFPP IV.

## 6. Lackluster and Substandard Performance of PDMAs

The provincial disaster management authorities PDMAs operate without adequate pre-positioned resources, integrated early-warning systems, or scalable evacuation protocols. Consequently during any floods, it is always the same result. Provinces are compelled to seek federal intervention rather than deploy the adaptation measures envisioned within the NDC framework.

The challenge remains in effective coordination. While coordination mechanisms are in place, in practice issues like delayed data-sharing, unclear roles, overlapping jurisdictions, and capacity constraints still hamper PDMA's operational response. Rapidly evolving risks like flash floods, cloud bursts, GLOF events, demand real-time coordination but we see that there are sometimes such long delays in response that critical time to save the victims is wasted resulting in eventual loss of lives.

In August 2025, an entire family of tourists drowned in the Swat River in KPK, after being caught in a sudden, devastating surge of floodwaters[8] —an avoidable tragedy caused by deep systemic failures. A provincial inquiry found that Rescue 1122's response was crippled by absent officers, untrained staff posing as divers, missing equipment, and critical delays that cost over an hour in an emergency where every second mattered. Early warning systems and key telemetry gauges were non-functional, while river flow reporting was delayed by four hours during which the water flow surged from 6,738 cusecs to a staggering 77,782 cusecs . The tragedy was compounded by illegal encroachments and a dangerously constructed temporary bund under an ADB-funded project, which misled tourists into believing the area was safe.

The Inquiry committee report concluded that widespread negligence, regulatory lapses, and administrative inaction directly contributed to the deaths of the entire family.

In a shocking revelation the secretary Irrigation department KPK reported to the committee that only 22 of the province's 131 installed gauges had a telemetry system.[9] Crucially, the telemetry gauges at Khwazakhela and Shamozai—both essential for flood forecasting—were non-functional during the tragic incident.

## 7. Lack of Early Warning Systems

During the 2025 monsoon season, there had been several major accidents in various districts which were the direct result of lack of proper early warning system which is the part of the NDCs. For example in the Swat tragedy where tourists were swept away by the flash floods they came for breakfast at a restaurant that was situated on the very edge of the river. The illegally built hotels and restaurants were not sealed or demolished before the flood season which was a case of negligence, oversight and lack of preparedness of the provincial and district authorities. Consequently, these businesses continued operating as usual, exposing tourists to the risk of flash flooding.

Residents of housing societies in Punjab located directly in the path of the Ravi floodwaters did not receive timely evacuation warnings. Consequently, many families were left stranded and later required rescue by boat.

The GLOF event at Ghizar in Gilgit Baltistan was spotted by a shepherd rearing his flock by chance and he was able to alert his village but the authorities were neither altered in time nor did they provide any warning to the at risk village.

In South Punjab, residents in many tehsils—including districts such as Jhang, Muzaffargarh, and Multan—were not given prior warning about the danger posed by the floods. These floods were deliberately diverted into their areas due to emergency breaches made in protective embankments (bunds) at various locations.

The system is reactive, not preventive. Instead of investing in early warning and preparedness, Pakistan spends billions after every disaster in compensation and rebuilding.

## 8. Outdated Infrastructure & Poor Maintenance

Even when early warnings exist, the physical flood protection infrastructure — embankments, drainage channels, barrages — is poorly maintained. Flood plans (like NFPP-IV) include schemes to strengthen these structures, but funding disbursement is delayed, Projects are politicized, Local irrigation departments lack accountability.Thus, technical preparedness lags behind hydrological reality.

## 9. Ill Conceived and Short Sighted Development

The floods of 2025 caused the most severe inundation south of Multan, specifically in the Jalalour Pirwala and

8 https://www.dawn.com/news/1920723
9 https://www.dawn.com/news/1923656

Ali Pur tehsils. In these areas, floodwaters from the Chenab and Sutlej rivers became stagnant, failing to drain downstream—a rare and catastrophic event attributed to two primary causes.

Firstly, experts point to serious design flaws in the newly retrofitted and remodeled Punjnad Barrage. Inaugurated in March 2025 at a massive cost of 200 Billion Pakistani Rupees, the barrage's curved design is believed to have blocked the river flow rather than easing it, causing water to back up severely upstream in Punjab.

Secondly, the flow of both the Chenab and Sutlej rivers was obstructed by the elevated embankments of the M5 Highway, which was completed just a few years prior. The gushing floodwaters could not follow their natural path downstream because the highway was constructed without adequate disaster planning. The design lacked necessary drainage provisions to handle high-flood eventualities. As a result of this massive failure and poor execution of the remodeling project at Punjad, thousands of acres of land was submerged in flood waters for weeks causing severe damage to land, crops and property.

## Structural Gaps in Disaster Management

Pakistan's disaster management system looks good on paper, but the reason floods keep escalating into national tragedies lies in the gaps between institutional design and ground-level execution.

### 1. Fragmented responsibilities

Although there is a hierarchy (NDMA ⊠ PDMA ⊠ DDMA), responsibilities often overlap or conflict. NDMA handles policy and coordination, PDMAs manages operations, and FFC & PMD, manage technical functions flood forecasting infrastructure. All these agencies report to different ministries and different chains of command, which causes coordination breakdowns. PMD and FFC report to the Ministry of Water Resources, not to NDMA — so early warnings and technical data does not always translate into timely community-level alerts.

There is no feedback or monitoring system at NDMA to make sure that their advisory, alerts or warnings have elicited a timely and robust response at the local levels at the vulnerable areas in the districts in any particular district.

PMD collects rainfall and forecast data, FFC monitors river flows, WAPDA manages dams, Provinces control irrigation and embankments. These systems don't always share live data, or do it manually and are delayed. The NDMA is currently unable to access data from weather stations installed in the upper northern areas and Gilgit-Baltistan through the GLOF Projects. The authority reports that despite repeated requests to the PMD for this data, it has not been provided. This lack of essential data sharing severely impedes the ability to formulate effective policy and undertake necessary preparedness measures.

There's no single integrated flood database accessible to all actors in real time. By the time NDMA issues national advisories, the water may already have breached local embankments.

### 2. Lack of Climate Change Mitigation Strategy

There is also chronic lack of coordination among the many bodies responsible for climate-related planning that rarely meet despite clear constitutional or statutory requirements. The Council of Common Interests (CCI)—the key forum for interprovincial coordination—convenes far less frequently than mandated, weakening the harmonisation of climate and environmental policies (CCI, 2023). Similarly, the National Economic Council (NEC) regularly misses its required biannual meetings, leaving economic decision-making disconnected from climate goals (NEC, 2022). Despite the inclusion of climate risks in the National Security Policy (2021), the National Security Council has not integrated climate risks into national planning (NSC, 2021).

The Pakistan Water Council, established in 2018, has reportedly met only once, preventing any unified, climate-aligned response to Pakistan's escalating water crisis (PWC, 2020). The Pakistan Environmental Protection Council has convened just twice in nearly forty years, and not once since the 18th Amendment reshaped the federal-provincial environmental landscape (PEPC, 2018). The Pakistan Climate Change Council, mandated to guide national climate action, also routinely fails to meet its biannual requirement (PCCC, 2022).

The National Disaster Management Commission, responsible for high-level policy and interprovincial coherence, has met only a handful of times since its creation in 2010, limiting the integration of climate science into disaster risk management (NDMC, 2023). The goal of generating 60% renewable electricity by 2030 is undermined by weak provincial coordination (Energy Ministry, 2024). Likewise, the implementation of the National Adaptation Plan requires cross-sectoral cooperation that dormant councils are unable to provide (NAP, 2023).As a result, there is no coordinated national strategy to confront accelerating climate risks.

## 1. National Disaster Management Authority (NDMA)

The NDMA is the central coordinating body for disaster management at the national level. It was established on August 17, 2007, initially under a National Disaster Management Ordinance. As the executive arm of the National Disaster Management Commission (NDMC), the NDMA's core mandate is to serve as the implementing, coordinating, and monitoring body for disaster management. Its key responsibilities include:

- Planning, implementing, coordinating, and monitoring the National Policy on disaster management.
- Laying down guidelines for the preparation of disaster management plans by various Ministries, Departments, and Provincial Authorities.
- Providing necessary technical assistance to Provincial Authorities for developing their disaster management plans.
- Coordinating the response in the event of any threatening disaster situation or actual disaster.

It chairs national coordination forums, convenes multi-agency meetings (including PDMAs, PMD, FFC, armed forces, UN/INGO partners) to align preparedness and response. For example, NDMA hosts daily "National Monsoon Coordination Conferences" in its National Emergency Operations Centre (NEOC) to monitor monsoon-related risk and ensure real-time information-sharing with PDMAs, PMD and others. NDMA's contingency plans (e.g., National Monsoon Contingency Plan) include SOPs for situation reports (SITREPs) where PDMAs, PMD, FFC and line-departments provide structured data to NDMA/NEOC at specified intervals.

However, the NDMA's recommendations are neither binding nor consistently considered before decisions are made at the federal or provincial level. NDMA does not affect or intervene in the Federal Flood Protection Plans neither can it alter it. The different authorities work in parallel and not necessarily in a coordinated fashion. Also there is no monitoring system in place at NDMA which can ensure that the advice or recommendations given by NDMA have actually been put in place at the provincial level. Because of this gap, NDMA cannot ensure adequate preparedness at provincial or district level.

NDMA has also not been able to take effective measures for climate change mitigation, adaptation techniques, or innovative disaster response strategies.

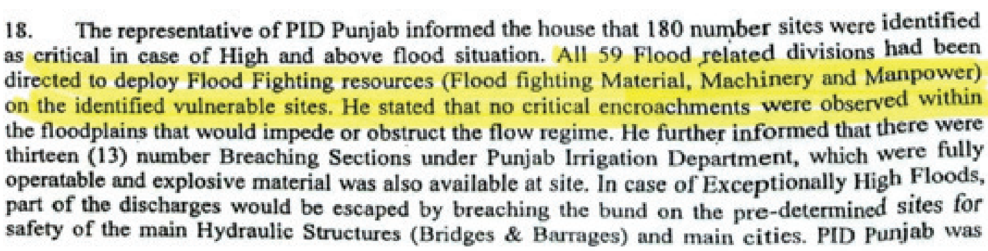
## 2. Federal Flood Commission (FFC) Ministry of Water and Resources

The Federal Flood Commission (FFC) was established in January 1977, for the purpose of integrated flood management at national level. The office of the Chief Engineering Advisor provides a secretariat for FFC, hence, it was generally named as 'Office of Chief Engineering Advisor & Chairman Federal Flood Commission (CEA&CFFC)'. FFC was established under the Ministry of Water and Resources (formerly Ministry of Water and Power) which is the main national body responsible for preparing, coordinating, and monitoring all National Flood Protection Plans (NFPPs).

The plans were meant to be implemented through the provincial line departments but these remained incomplete and ineffective. The provincial governments have failed to incorporate the flood protection plans in their development agendas including urban planning and river infrastructures.

On the 4th of June 2025 there was a very important meeting held at the office of the Federal Flood Commission under the chairmanship of the Minister for Water Resources Mian Moeen Wattoo. The minutes of this meeting are available on the website of the FFC.[10] For anyone who wants to understand the role of FFC and the nature of coordination between this important body and the federal and Provincial line departments, this document provides a wealth of information and would be an excellent reference for any research, now and in the future.

Just to quote one example, when the chair inquired about the preparedness in flood plains from the representative of the Punjab Irrigation Department, he categorically gave the answer that all the fifty nine vulnerable sites have been provided with 'flood fighting resources including materials, machinery and man power and there were NO critical encroachments within the flood plains that would impede or obstruct the flood regime.

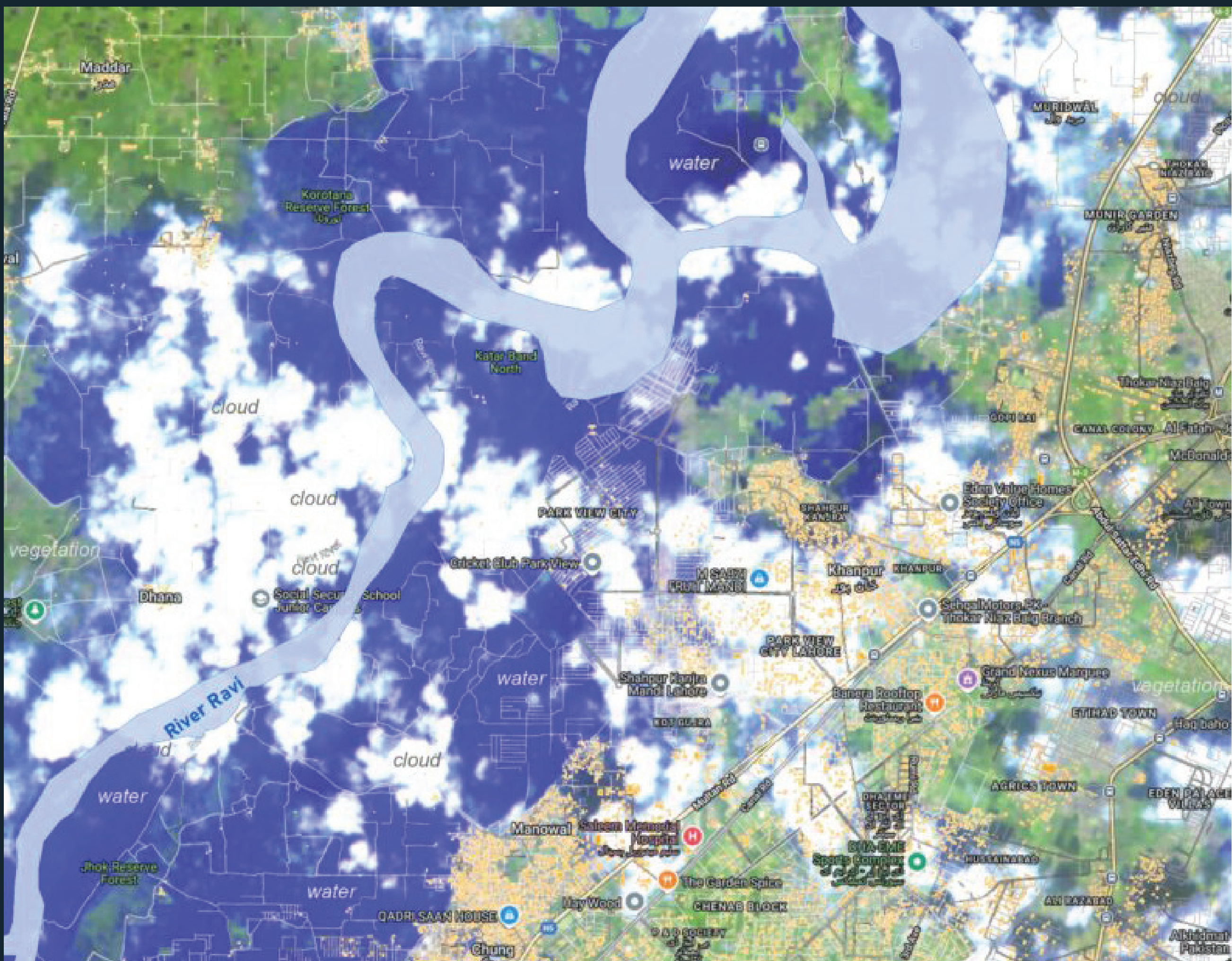

18. The representative of PID Punjab informed the house that 180 number sites were identified as critical in case of High and above flood situation. All 59 Flood related divisions had been directed to deploy Flood Fighting resources (Flood fighting Material, Machinery and Manpower) on the identified vulnerable sites. He stated that no critical encroachments were observed within the floodplains that would impede or obstruct the flow regime. He further informed that there were thirteen (13) number Breaching Sections under Punjab Irrigation Department, which were fully operatable and explosive material was also available at site. In case of Exceptionally High Floods, part of the discharges would be escaped by breaching the bund on the pre-determined sites for safety of the main Hydraulic Structures (Bridges & Barrages) and main cities. PID Punjab was

Minutes of the FFC meeting

10 https://ffc.gov.pk/wp-content/uploads/2025/08/Minutes-of-60th-Annual-meeting-of-FFC-2025.pdf

In actuality after the Ravi river inundated the flood plains, scores of residential areas that had been built on the river's floodplain were heavily inundated. In Lahore, the localities of Shafiqabad, Farrakhabad, Tallat Park, Theme Park, and Park View City were flooded. In some blocks of Park View City, water levels reached three to six feet, damaging roads, electricity lines, and drainage systems. Across Punjab, an estimated 161,700 houses were damaged (28% fully destroyed, 72% partially damaged). Water works, electricity networks, and sewerage systems sustained significant damage in many affected districts. Across 18 affected districts in Punjab, 667 schools and 395 health facilities were reported as damaged.

The satellite imagery shows that the river Ravi did not exceed beyond its flood plains at any stage of the flood but there were thousands of encroachments in its historic flood plains.[11]




River Ravi European Space Agency ESA Sentinel-2 Imagery August 29 2025

### 3. Dam Safety Council (DSC)/ Ministry of Water and Resources

The Dam Safety Council (DSC) was established in 1987 in the Office of the CEA&CFFC to carry out inspections of existing dams and to review plans for new dams. It also formulated Flood Plain Inundation Maps of major Rivers and district level. It was mandated to formulate Model River Act for Provinces & FLAs to restrict encroachments, do the scrutiny of flood control/protection schemes funded by Federal Government and prepared by Provincial Governments and Federal Agencies, do the review of damage of flood protection works and review of plans for restoration and reconstruction works, measures for improvement of Flood Forecasting & Warning System, preparation of research programme for flood control and protection, standardization of designs and specifications for flood protection work, and recommendations regarding principles of regulation of reservoirs for flood control. It was also meant to do evaluation and monitoring of progress of implementation of the National Flood Protection Plans.

11 The UNOSAT's latest analysis of satellite detected water on August 29 in Punjab province, showed that about 3,660 $km^2$ of land was affected by floodwaters within an analyzed area of 88,300 $km^2$. An estimated 2.5 million people are potentially exposed.

The Dam Safety Council's performance is questionable, as evidenced by the aftermath of the 2025 Punjab floods. The massive flood damages from the Chenab RIver inundation were partly due to the complete failure of two barrages—Trimmu and Punjnad—to safely pass the floodwaters. This failure occurred despite an approximately USD 150 million remodeling project meant to enhance capacity.[12] The Trimmu–Panjnad rehabilitation project was a part of a $700 million multi-tranche finance facility for the Punjab Irrigated Agriculture Improvement Programme. [13]

### 4. Pakistan Meteorological Department (PMD)

PMD, the key department for early warning systems, is a federal department based in Islamabad. Its function includes the timely relay of weather reports and situation reports to NDMA and all federal and provincial stakeholders.[14]

### 5. Provincial Irrigation Department

The key institution responsible for flood monitoring and management is the Provincial Irrigation Department, which operates in Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan, Azad Jammu and Kashmir, and Gilgit–Baltistan.

The Punjab Irrigation Department is perhaps one of the most important provincial departments in Pakistan with regards to river management because Punjab has the largest canal irrigation system in the world. Its core mandate is the management, regulation, and protection of surface water resources across the province.The department is responsible for, operating barrages and headworks, regulating canal water distribution, maintaining canals, distributaries, minors, and watercourses. Its responsibilities include monitoring river flows, maintaining flood embankments and spurs, strengthening river training works, emergency flood response coordination and repairing breaches. It is also mandated to design and execute new canals, link canals, flood protection works, small dams, river improvement projects.

Given the paramount importance of this department, the appointment of its minister demands careful consideration. It is perplexing, however, that the appointed minister frequently lacks the technical expertise necessary in fields such as hydrology, river engineering, or irrigation management. This department fundamentally requires, and must be led by, an expert in the relevant science and technology. However this is hardly the case in actuality.

During the 2010 Indus super flood, for instance, the portfolio of this extremely important department was held by Raja Riaz, a Pakistan Peoples Party minister whose appointment reflected political compromise rather than domain-specific experience. Contemporary accounts note that he maintained limited engagement with the department's operations. As the floods intensified and as mismanagement—including the diversion of river flows into canal systems[15] —reportedly contributed to extensive damage amounting to billions of dollars, the minister was largely absent from the crisis response and played no visible role in directing or overseeing the department's actions during the emergency.

#### Case Study

The 2010 Indus flood in Pakistan are widely regarded as a disaster significantly exacerbated by human error, institutional failures, and severe mismanagement of floodwaters at key barrages. The Flood Fact-Finding Commission—constituted in the aftermath of the disaster—conducted an extensive inquiry and produced the report A Rude Awakening. The Commission's findings attributed substantial responsibility for operational mismanagement of river flows, barrages, and canal systems to both the Punjab and Sindh governments. It further noted that several critical and ill-timed administrative decisions, including those taken at the highest provincial levels, including the Chief Minister Punjab, contributed to the scale of devastation.

According to the Judicial Flood Fact Finding Tribunal 2010 report, 1, Chapter 3," that during High/Medium Flood, all gates of the barrage are opened and repair work( upstream or downstream) is stopped so that the water may pass through the barrage without causing and damage to the structure of the barrage. During recent floods, it has been observed that in the third week of July. Medium/High flood arrived in the river, however neither the gates were opened not stone dumping work was stopped. On 27.07.2010, high flood was observed. On 29.07.2010 till noon the water discharge was noted as 6,25,000 Cfs. When the information was received from Tarbela Dam that 200,000 Cfs was heading to the barrage the officers opened the barrage gates but due to the high pressure of the water the gates were opened with difficulty. Consequently, LMB was completely washed away which caused damage of 80 to 90 crore to the national exchequer. It is astonishing that incompetence and corrupt officers due to their personal greed caused loss to the barrage structure and LMB( 4500 ft), out of which only 50 ft remained intact and the remaining portion completely washed away. "

12 Media/technical commentary after the 2025 monsoon floods noted that Panjnad's rehabilitation had only recently been completed (March 2025) and quoted design targets (reports cited an 850,000 cusec design/pass capacity target for the rehabilitated works). However, observers reported that flood peaks in 2025 (≈550,000–680,000 cusecs in some peaks) still produced serious downstream inundation, and that in places the upgraded structures and associated river works did not prevent large-scale flooding — often because operational, maintenance, encroachment, or system-level issues
13 https://tribune.com.pk/story/802544/assistance-adb-commits-150m-for-rehabilitating-barrages?utm_source=chatgpt.com
14 ndma.gov.pk+1
15 https://www.thefridaytimes.com/31-Jul-2015/in-floods-defense

Although the Commission's report documented these failures in detail, it was never formally published, and only a limited number of copies circulated unofficially. Public discourse and the media, at the time framed the floods as an act of divine will or an unavoidable force majeure event, reinforcing the perception that the disaster lay beyond human control. In reality, the Commission identified a chain of questionable decisions, improper breaching operations, and inadequate gate management at Taunsa Barrage that diverted floodwaters well beyond natural floodplains and into densely populated areas. Despite the magnitude of the failures identified, no meaningful accountability followed; no officials were held responsible, and the government response was largely confined to the distribution of limited relief assistance

### 6. Provincial Disaster Management Authorities (PDMAs)

PDMAs are mandated with coordination and emergency response at the provincial level and act as the focal authority within each province for disaster preparedness, response and recovery. They coordinate horizontally with line departments (Irrigation, Health, Communications etc) and vertically with district authorities (DDMAs) and the NDMA/federal level. [16] PDMAs receive early-warning data from PMD/FFC, deploy local response and liaise with NDMA when federal assistance is required.[17] PDMAs issue local alerts, coordinate evacuations— thus ensuring vertical link from federal forecast to provincial/local execution.

However the PDMAs have no role in policy decisions at the provincial level. Their role remains limited to contingency planning or rescue and relief. The 2025 floods in Punjab highlighted a failure in the early warning system which was one of the responsibilities of PDMA Punjab.

Prior to the 2025 monsoons, the Punjab Flood Forecasting Department issued an initial alert and a subsequent warning to the Provincial Disaster Management Authority (PDMA) by August 20th, detailing the expected flow levels in the Ravi and Chenab rivers. Despite these timely warnings—with maximum flow levels in the Ravi peaking on August 26th and 27th—communities residing along the riverbanks did not receive the early warning in time. Consequently, many were caught off guard and stranded by the rising floodwaters of Ravi river reaching extreme high level at 240,000 cusecs.

### 7. District-level disaster management authorities (DDMAs)

DDMAs who are responsible for warning communities — are mostly dysfunctional. Even if there is timely advice from the federal agencies that does not translate into effective preparedness at the district level. In the floods of 2025, there had been three major incidents of flash floods in Swat River on date, Diamere Chilas land sliding on, and Buner land sliding, with extensive loss of life, where the disaster victims were left helpless for hours fending for themselves but in all these three incidents there was no preparedness seen at the district level. The local district administration was totally incapable of managing the accidents. There was no early warning issued to the local community and there was not even any rudimentary equipment available for any search and rescue.

Resultantly even when NDMA and PMD issue alerts, they are not relayed timely to the local at risk communities local administrations. There is no mechanism set in place whereby the alerts and advisories are taken as instructions and translated into action.

Advisories issued by the Pakistan Meteorological Department (PMD) and the National Disaster Management Authority (NDMA) are often generalized, meso-level situation reports rather than location-specific alerts pinpointed to the district level. Consequently, district administrations frequently treat these routine advisories, which are typically uploaded to the PMD or NDMA websites, as business-as-usual, resulting in minimal proactive action.

It is therefore incumbent upon the Provincial Disaster Management Authorities (PDMAs) to translate these generalized warnings and utilize their own mapping resources to identify and pinpoint specific vulnerable areas within their jurisdiction.

## During and Post Disaster Rescue, Recovery, Relief and Rehabilitation

Following a flood, a flurry of post-disaster activity usually ensues. However, accountability is frequently absent: no questions are asked, and no responsibility is assigned to national or provincial disaster managers. Furthermore, no inquiries are held to determine if those responsible adhered to standard operating procedures (SOPs). Consequently, these events fail to establish institutional memory, and no meaningful lessons are learned for future preparedness. The usual post disaster activities remain to be emergency response units for rescue and evacuation, relief to the affectees, loss and damage assessments and later reaching out to the

16 pdma.gop.pk+2ndma.gov.pk+2
17 ndma.gov.pk

international donors for financial aid and assistance. No real effort is made by the governments to determine the localized causes of flood damage in particularly hard hit areas in order to ensure better preparedness.

- **Pakistan Army / Frontier Works Organization (FWO).** During and post disaster, Pak Army usually takes the lead in emergency response, rescue, recovery and relief.
- **Activation of EOCs:** On disaster occurrence, EOCs at national (NEOC) and provincial levels are activated; liaison officers from NDMA, PDMAs, PMD etc are nominated and coordinated via web/tele-conference systems.
- **Data & Reporting Chains:** Daily SITREPs and situation updates from PDMAs, PMD, FFC to NDMA; information on early warnings, resource status, evacuation, relief goods etc.
- **Resource mobilisation and escalation:** Resource mobilization and relief is usually initiated by the Provinces. Should local and provincial resources become exhausted, the National Disaster Management Authority (NDMA) intervenes. This national-level assistance includes providing logistics, financial support, and the deployment of armed forces. Furthermore, the NDMA is responsible for initiating requests for international aid if the situation necessitates external assistance.

## The Way Forward:

### 1. Need for Provincial NDCs:

Among the gaps identified above, perhaps the all encompassing one is the lack of any provincial level NDCs or PDCs, as they might be called, as opposed to commitments made by the federal government.

Natural hazards that frequent Pakistan have different impacts in each province. KPK is prone to flash flooding and land slides, south punjab and parts of baluchistan are vulnerable to hill torrents, Central Punjab is at risk of riverine floods etc. Each province must develop its own Provincially Determined Contributions (PDCs), which necessitates assessing unique vulnerabilities and formulating responses that are led at the local level.

Sindh, for instance, faces risks from seawater intrusion and coastal inundation, especially during hurricanes and sea storms. Therefore, it needs to allocate funds for mangrove restoration and the construction of coastal defenses. Karachi particularly is affected by urban flooding and it needs to allocate funds for making storm drains and rain water drainage systems. As Sindh is also affected by heat waves then there should be adequate funds allocated for combating urban heat phenomenon through specific Green programmes including tree plantation in Karachi, and Hyderabad.

Punjab is required to assess water scarcity in the districts of Bahawalpur and Multan and allocate budget resources for provision of water; urban heat mitigation measures in Lahore, Multan and Faisalabad as well as improve air quality in these districts. Balochistan's priorities should include mapping drought vulnerability, rain water harvesting, resilient fruit farming and allocating budget for rangeland management.

Khyber Pakhtunkhwa (KP) and Gilgit-Baltistan (GB) must prioritise risk reduction of land and mud sliding, massive deforestation and Glacial Lake Outburst Floods (GLOF). KPK needs to allocate budgets for enhanced disaster preparedness and early warning systems in areas most vulnerable to risks of flash flooding and landslides.

As it is, provincial finance departments do not tag climate expenditures or disaster preparedness in annual budgets.

### 2. Need for existing NDC's alignment for all provincial planning

In order to make any progress, NDC alignment for PC-1 approvals has to be made mandatory. The governments must be made accountable for prioritising budget spending on climate change adaptation, increasing resilience and reducing the vulnerabilities at the district level so that with each passing year the communities are better prepared to face the inevitable natural hazards. This should be the revision of all policy and regulations aligned with the NDCs so that there is no development or any projects that clash with the agenda of comprehensive disaster preparedness, planning and execution.

### 3. Hazard, Vulnerability and Risk Mapping and Data Base

All provinces must conduct a comprehensive district-wise, complete hazard, vulnerability and risk assessment. The resulting data must be maintained in an up-to-date, live data base connected to all critical departments at the federal level, including the Meteorological Department (MET), the National Disaster Management Authority (NDMA), and the Federal Flood Commission (FFC). This centralized database must also be accessible at the district, tehsil, and Union Council (UC) levels. The purpose of this system is to ensure that everyone in the entire disaster management chain possesses the exact same, current information at the same time.

### 4. Automated Alert System

The provincial core Risk and Vulnerability database must function as an automated alert system. For instance, upon receiving a warning of excessive rainfall in any specific area in any district, the system should automatically process this data, determine the precise risk category, and issue the corresponding alert (Yellow, Orange, or Red). This critical alert must be instantly accessible to all relevant stakeholders, including disaster managers, the district administration, rescue agencies, local police stations, and local hospitals. It can be relayed as text message or alarm on the phone or in case of emergency, it can also automatically trigger sirens in the at risk area.

Crucially, comprehensive and frequently practiced systems and Standard Operating Procedures (SOPs) must be firmly established at both the district and local levels. These procedures should cle arly define the sequential actions that should come into motion, immediately upon the issuance of a Yellow, Orange, or Red alert. The SOPs (Standard Operating Procedures) must clearly assign responsibilities to all managers and stakeholders, including local entities such as mosques, dispensaries, and volunteer civic organizations.Strengthening institutional effectiveness is not a procedural necessity; it is the foundation upon which Pakistan's disaster management and climate resilience must be built. The cost of inaction—measured in lives, livelihoods, and mounting economic losses—is already too high, and rising.

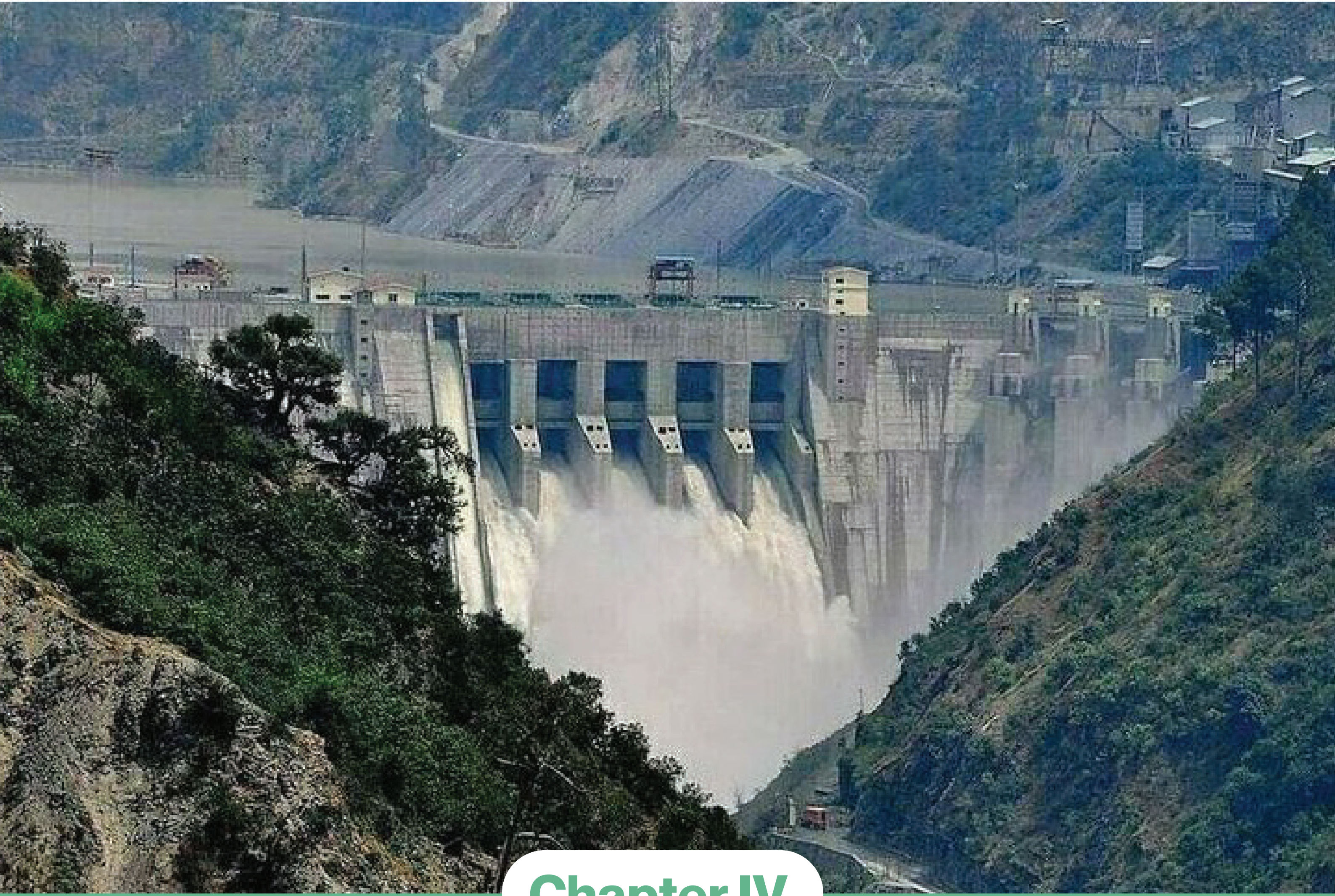
### In conclusion:

There are important case studies and lessons to be learned from the floods 2025. The flooding along the Ravi River caused catastrophic damage to riverine communities, largely because the Punjab Government permitted extensive housing development inside designated floodplains (Punjab Development Authority, 2025). This approach directly contradicted long-established principles of flood zoning, which require strict prohibitions on construction in high-risk zones (Flood Zoning Guidelines, 2019).

The disaster illustrates the stark disconnect between scientific recommendations and provincial development decisions. It also exposed the failure of multiple institutions—ministries, commissions, and authorities tasked with flood prevention—to enforce basic safeguards. Similarly the Swat tragedy could have been prevented by the timely action of provincial and district governments to make sure that there were no illegally built hotels etc on the river which could put the tourists at risk

Despite hundreds of meetings, advisories, and official correspondences no federal or provincial body succeeded in stopping either the Punjab or Khyber Pakhtunkhwa governments from permitting encroachments on riverbeds. This systemic failure shows that provincial development plans often operate independently of national climate policies, including the Flood Protection Plan (Federal Flood Commission, 2020), the National Climate Change Policy (MoCC, 2021), Pakistan's Nationally Determined Contributions (NDCs) submitted to the UNFCCC (UNFCCC, 2021; UNFCCC, 2023)

**Last Word:** A sustainable solution for disaster management also requires a province-wide and long-term programme of public awareness, including climate change and disaster preparedness education embedded within school curricula . Without a climate-literate population, Pakistan cannot build resilience from the ground up.



Chapter IV

# PAKISTAN'S RECURRENT FLOODS:

## Lessons Unlearned, Climate Realities, and the Imperative for Regional cooperation

Ali Tauqeer Sheikh

Pakistan is lurching from one flood disaster to another. The 2010, 2022, and 2025 floods tell a story not just of climate change, but of institutional paralysis, unlearned lessons, and a dangerous regional cooperation deficit that costs Pakistani lives.

## Introduction

On August 27, 2025, in the village of Rajanpur in southern Punjab, Amina Bibi heard the sirens too late. The flash flood from the Chenab River—swollen by cloudbursts in Indian-controlled Kashmir just six hours earlier—swept away her home, claiming the lives of her two young children. There had been no advance warning from Pakistani authorities. The meteorological data from Indian stations that could have provided crucial early notice was never shared.

Amina's story is not unique. It represents one of over 1,000 deaths in Pakistan's 2025 floods—deaths that were, in significant measure, preventable.[1]

This chapter examines Pakistan's recurring flood crisis through four interconnected lenses, each revealing a dimension of failure that demands urgent correction.

First, Pakistan's floods are becoming more devastating and more diverse. The 2010, 2022, and 2025 disasters demonstrate escalating human and economic costs, with floods diversifying beyond traditional riverine patterns to include cloudbursts, landslides, glacial lake outbursts, torrential rains, urban flash floods, and tropical storms.[2] Our institutions, however, are not learning or adapting. Pakistan remains trapped in a pattern of repetition: we identify failures after each flood, commission reports, announce reforms, and then repeat the same mistakes when the next disaster strikes.

Second, climate change is making floods more frequent, more ferocious, and more diverse by altering temperature and precipitation trends. Several research studies have established clear links between anthropogenic climate change and the intensity of Pakistan's 2022 and 2025 floods.[3] The attribution is no longer ambiguous. Studies show that climatic changes intensified the 2022 monsoon by approximately 75 percent and the 2025 event by 10-15 percent. More critically, warming is introducing new flood types—glacial lake outbursts, compound extremes where heatwaves amplify monsoon impacts, monsoon rains in non-monsoon areas, and cloudbursts in areas with no historical precedent. Pakistan faces not just worse versions of familiar disasters, but entirely new categories of hydrometeorological risks.

Third, Pakistan and India are ecologically linked through shared river basins, deserts, the Hindu Kush-Karakoram-Himalaya cryosphere, and monsoon weather systems. This hydrological continuity means that extreme weather events in India—heatwaves, droughts, tropical storms, cloudbursts, glacial outbursts—cascade downstream into Pakistan with amplified force. Pre-monsoon heatwaves dry soils, increasing runoff by 30-40 percent when rains arrive. Cloudbursts in Indian Kashmir send flash floods into Pakistan within hours. Glacial lake outbursts in Indian-controlled areas contribute to unprecedented river flows downstream. Pakistan, as the lower riparian country, bears disproportionate consequences from upstream climate impacts.

Fourth, India and Pakistan have failed to build the scientific collaboration, information exchange systems, and early warning mechanisms that could reduce flood damages by 30-50 percent. The absence of real-time data sharing, joint flood forecasting, and coordinated glacial lake monitoring directly worsens downstream impacts in Pakistan. India's decision to suspend aspects of the Indus Waters Treaty has exacerbated the situation. The 2025 floods in Pakistan's three eastern rivers—fed by flows from India—demonstrated this failure starkly: inadequate advance warning, no shared meteorological data, and no coordination during critical flood periods resulted in higher flood levels, greater economic losses, and increased casualties.

These four realities—institutional paralysis, accelerating climate change, transboundary hydrological linkage, and regional cooperation failure—have combined to create an escalating crisis. Understanding each dimension is essential. Addressing all four simultaneously is imperative.

## Three Disasters, One Pattern: 2010-2025

Pakistan has endured three catastrophic floods in fifteen years. This escalating destruction was not due to lack of warnings but because critical lessons from earlier disasters were inadequately grasped, poorly addressed, or altogether ignored.

### A. 2010: The Initial Warning

The 2010 floods submerged nearly one-fifth of Pakistan's land, resulting in approximately 2,000 deaths and affecting 20 million people. Economic losses totaled $10 billion, with 1.9 million homes destroyed, 10,000 schools severely damaged, and over 5,000 miles of roads washed away.[4]

1 NDMA Flood Situation Report, August 2025
2 (ICIMOD), Regional Cryosphere Monitoring Report: Hindu Kush Himalaya (Kathmandu: ICIMOD, 2024)
3 https://www.worldweatherattribution.org/
4 https://reliefweb.int/report/pakistan/pakistan-floods-emergency-response-plan

Following the disaster, Pakistan's Supreme Court appointed a commission to investigate, producing a comprehensive report in 2011. The Lahore High Court separately conducted a provincial inquiry focused on Punjab's flood management failures, producing a report titled "A Rude Awakening". However, these judicial findings were largely shelved—the Punjab government never publicly released the full tribunal report, and recommended actions against negligent officials were not implemented.

The disaster revealed deep systemic failures: ineffective early warning systems, poor federal-provincial coordination, absence of transboundary cooperation with India, fragile infrastructure, and insufficient climate adaptation investment. These findings would prove prophetic—and tragically, unheeded.

### B. 2022: The Climate Wake-Up Call

In 2022, floods affected 33 million people and inflicted economic damage estimated at approximately 10 percent of GDP—around $30 billion in combined damages and losses. The scale was unprecedented, exceeding the combined population of several smaller nations.

The Pakistan Floods 2022 Post-Disaster Needs Assessment (PDNA), published in October 2022 with support from the World Bank, Asian Development Bank, European Union, and UN agencies, fundamentally reframed Pakistan's understanding of vulnerability. The assessment estimated $14.9 billion in damages, $15.2 billion in losses, and $16.3 billion in resilient reconstruction needs across 94 calamity-hit districts. Alongside the PDNA, the government launched the Resilient Recovery, Rehabilitation, and Reconstruction Framework (4RF), emphasizing "build back better" principles with climate-resilient recovery through nature-based solutions, risk-informed planning, and multi-sectoral resilience. Recovery was positioned not merely as reconstruction but as a vital opportunity to embed climate resilience systematically into national planning.

The PDNA's diagnosis was robust, but its implementation mechanisms were weak. Policy recommendations centered on embedding risk assessments within the Planning Commission's project approvals and strengthening district-level disaster management capacity. However, the PDNA outlined what needed to be done but left budgets, institutional mandates, timelines, and enforcement mechanisms to the government's discretion. This approach created predictable implementation gaps that became apparent as floods recurred in 2025.

### C. 2025: Predictable Catastrophe

By September 2025, floods had claimed over 1,000 lives, including hundreds of children. Collapsing homes remained the leading cause of death.[5] A new threat emerged prominently—glacial lake outburst floods from the warming Hindu Kush-Karakoram-Himalaya region—yet core institutional failures endured unchanged.

Pakistan's Preliminary Assessment of Flood Damages, released by the Planning Commission in September 2025, represents the country's first official damage estimate. However, the assessment reveals methodological weaknesses: ad hoc data compilation without systematic verification, critical district-level data gaps, and only superficial mention of Pakistan's climate vulnerability.

Most troubling is what the assessment omits. Neither the Ministry of Climate Change nor prior climate-focused assessments—including the 2022 PDNA and 4RF—are referenced, raising questions about whether lessons from these frameworks guided current planning. No mention appears of Pakistan's Paris Agreement obligations, National Adaptation Plan, Nationally Determined Contributions, or National Climate Change Policy.

The failure to operationalize the 2022 PDNA's recommendation to embed climate risk screening within the Planning Commission's project approval process directly contributed to repeated destruction. A major section of the M-5 motorway—reconstructed after 2022—was destroyed again in 2025. Over 8,400 houses were lost, many rebuilt in the same vulnerable locations without resilient construction standards. This starkly reveals that "build back better" principles remain unrealized.

Other systemic failures persisted: absence of climate risk screening in major infrastructure investments, unimplemented resilient construction standards, absence of functional district-level disaster management authorities, and lack of adaptive social protection programs. These factors measurably worsened flood impacts on vulnerable communities. The 2025 floods were not caused by ignorance but by enduring institutional and political failures.

## The Climate Imperative: Science Of Escalating Risk

Pakistan's flood crisis cannot be understood without confronting climate science. The evidence is definitive: anthropogenic climate change has emerged as the dominant driver transforming Pakistan's hydrological risk landscape.

### A. Attribution Science:

The World Weather Attribution (WWA) study on the 2025 floods provides unambiguous evidence: climate change intensified the monsoon rainfall by 10-15 percent and made such events at least three times more likely.[6] In today's climate, warmed by 1.3°C above

5 https://reliefweb.int/report/pakistan/pakistan-floods-emergency-response-plan

pre-industrial levels, this type of catastrophic event now occurs approximately every five years. What was once rare is now routine.

The 2022 floods demonstrated even stronger climate attribution. Research established that the event's intensity was approximately 75 percent greater than it would have been without human-caused warming. The trend is unmistakable: climate change is not simply making floods worse—it is fundamentally transforming Pakistan's hydrological reality.

The physical mechanism is straightforward. A warmer atmosphere holds approximately 7 percent more moisture per degree Celsius of warming. Pakistan is experiencing this basic physics as devastation. Parts of Sindh and Balochistan recorded rainfall 500-700 percent above average during July-August 2025. The Arabian Sea, warmer than historical averages, pumped unprecedented moisture into the monsoon system. Since the 1960s, Pakistan's mean annual temperature has increased by approximately 0.6°C, with projections indicating a rise of 3°C to 6°C by century's end under moderate to high emissions scenarios. Northern regions are warming faster than the south. This warming manifests in more frequent and intense heatwaves. In April 2025 alone, temperatures in Punjab and Sindh reached 45°C—some 4-7°C above normal—leading to school closures, power shortages, and heightened health risks.

### B. Compound and Cascading Risks

Precipitation patterns have shifted dramatically. While overall rainfall shows a slight nationwide increase over the past 50 years, the distribution has become markedly more variable and intense. Monsoon rains, which deliver 80 percent of Pakistan's annual precipitation, have become heavier and more erratic. Climate models and observations confirm that extreme rainfall events are now 15-75 percent more intense due to warmer air holding more moisture.

The 2025 floods introduced a dimension barely present in 2010 and only emerging in 2022: glacial lake outburst floods. As temperatures soar in the Hindu Kush-Karakoram-Himalaya region, glaciers are melting at accelerating rates, creating growing glacial lakes that can burst without warning.

Pakistan has over 7,000 glacial lakes in its northern mountains. Each represents a potential outburst risk. In 2025, over 50 GLOFs were reported across Gilgit-Baltistan and Khyber Pakhtunkhwa. Glacial melt contributed an estimated 20-30 percent of peak flow in upper Indus reaches. The HKH region is warming at rates exceeding the global average, with formation of new glacial lakes increasing GLOF risk exponentially. These changes ripple into cascading hazards. Droughts have intensified in rain-fed regions like Balochistan, where reduced winter precipitation combines with heat to parch soils and spike food insecurity. Landslides proliferate in deforested northern hills during erratic heavy rains. Compound extremes—pre-monsoon heatwaves followed by intense monsoons—have become routine. Analysis of 73 years of Hindu Kush-Himalayan data shows floods significantly more frequent since the early 2000s.

This is Pakistan's climate future: compound extremes where intense monsoons combine with glacial outbursts and pre-monsoon heatwaves that dry soils and increase runoff by 30-40 percent. Pre-monsoon heatwaves, which historically occurred 5 days annually, now occur 15+ days annually since 1980.

### C. Future Projections:

The IPCC Sixth Assessment Report projections are unambiguous: under high-emissions scenarios, extreme monsoon events will increase in both frequency and intensity. GLOF risk will continue escalating as glacial melt accelerates. Compound extremes will become more common. Current adaptation measures will become increasingly inadequate.

The severity and pace of current climate-linked extreme weather events are accelerating far beyond previous projections. The 2025 Pakistan floods starkly demonstrate that many catastrophic events previously projected to occur around 2050 have already materialized in 2025. This acceleration signals that the window for gradual adaptation has closed. The catastrophic future once feared is now the present reality.

Under scenarios projecting 2.6°C warming above pre-industrial levels, catastrophic flood events will transition from rare occurrences to regular realities. Current climate models underestimate observed increases in extreme rainfall by nearly 50 percent. This means Pakistan's actual future risks likely exceed even the dire scenarios climate scientists have modeled. The 2025 floods represent not an anomaly, but a preview of Pakistan's climate future.

## Shared Ecosystems, Separate Disasters: The Transboundary Dimension

As literary journalist David Jiménez observed, South Asians are bound by an ecosystem that inseparably links regional resilience through climate realities. Pakistan and India share the Indus basin, the Hindu Kush-Karakoram-Himalaya cryosphere, and monsoon weather systems. But we do not share data, forecasts, or early warnings. This deficit kills Pakistanis.

## A. Ecological Interconnection:

The Indus River system comprises six major tributaries—eastern rivers (Beas, Ravi, Sutlej) and western rivers (Indus, Jhelum, Chenab). These shared waters account for over 90 percent of Pakistan's agricultural water use and support seven Indian states and territories. Heavy monsoons and poor transboundary management increasingly cause deadly flooding in Punjab and Sindh's floodplains.
The Hindu Kush, Karakoram, and Himalayan ranges form interconnected geological features spanning northern India through multiple states, extending westward into Pakistan's Gilgit-Baltistan. These ranges converge near Jaglot in northern Pakistan. This complex system houses some of the world's largest glaciers and has become a hotspot for glacial lake outburst floods.

The Thar Desert spans both countries, spreading desertification and drought. The vast Indus River Delta mangroves are divided between Pakistan and India's Gujarat coast, depending on Arabian Sea tidal waters and Indus River freshwater flows. The Rann of Kutch, a unique seasonal salt marsh straddling the border, serves as a flooding basin during monsoons.
Climate disasters create predictable chain reactions: upstream heatwaves trigger downstream flooding, mountain glacial bursts cause delta flooding, and Arabian Sea storms affect the entire coastal ecosystem sequentially. Almost all climate-triggered events—floods, heatwaves, droughts, GLOFs, and tropical storms—when originating in India, cascade downstream to Pakistan with amplified effects.

## B. Case Studies of Cascade Effects

Kashmir Floods (2014): Unprecedented floods caused by heavy post-monsoon rains devastated the Kashmir region and downstream areas in both countries. The disaster originated from Indian-controlled Kashmir's meteorological conditions, with the Jhelum and Chenab rivers swelling beyond danger levels, submerging Srinagar and numerous villages. The floods then followed the natural downstream flow into Pakistani Punjab, affecting over 1.1 million people, inundating more than 700 villages, and causing at least 280 deaths. This pattern was replayed vividly in 2025.

Transboundary Heatwave (2022): The spring 2022 heatwave originated in India's northern plains before sweeping into Pakistan, breaking temperature records and reaching over 49°C. In India, the heatwave severely damaged wheat crops, reducing yields and spiking global wheat prices. As the heatwave moved downstream into Pakistan, it triggered cascading disasters—accelerated glacier melt leading to GLOFs and intensified rains that worsened the catastrophic 2022 floods, submerging a third of the country.

Arabian Sea Cyclones: Tropical cyclones forming in the Arabian Sea typically develop closer to India's longer coastline before affecting Pakistan's coastal regions. Cyclone Tauktae (2021), one of the deadliest Arabian Sea cyclones, devastated India's west coast before bringing destructive rain and ferocious winds to Pakistan, forcing evacuations and infrastructure disruptions.

## C. The 2025 Experience: Cooperation Deficit in Action

In the 2025 floods, the consequences of non-cooperation were stark and deadly. Cloudbursts in Indian Kashmir between July 15-20 sent torrents into Pakistan within 4-6 hours. Pakistani authorities had no time to issue effective warnings. Multiple glacial outbursts from Indian-controlled areas contributed to unprecedented flows in the Chenab River.

Pakistani hydrological models underestimated total basin precipitation by 30-40 percent because they lacked rainfall data from Indian meteorological stations. This systematic information gap produced cascading failures: delayed warnings reduced evacuation time, inadequate advance notice prevented optimal dam operations, and communication breakdowns during peak flooding (July 25-30) prevented coordinated reservoir management.

Every category of extreme weather in India has amplified downstream impacts in Pakistan.
Pre-monsoon heatwaves across the Indo-Gangetic plain dry and compact soil, reducing absorption capacity. When monsoon rains arrive, runoff increases by an estimated 30-40 percent. That water flows into Pakistan with no advance notification.

## D. The Cost of Non-Cooperation:

Research indicates that effective transboundary cooperation could reduce flood damages by 30-50 percent through timely warnings. Analysis of the 2022 floods suggests that inadequate early warning increased economic losses by $5-8 billion. Lives could have been saved, property protected, and livelihoods preserved.

This is not speculation as the data is clear: every casualty from inadequate warning represents a failure of regional cooperation. Every collapsed house that could have been evacuated represents a political choice to allow institutional paralysis to continue. Every lost life is a consequence of this systematic failure.

## E. Global Lessons:

Functional transboundary systems exist elsewhere, demonstrating that technical cooperation can survive—and even thrive—amid political hostility. The Mekong River Commission, spanning Cambodia, Laos, Thailand, and Vietnam, achieves 90 percent real-time data sharing and provides 5-7 day advance warnings despite periodic bilateral tensions.

The Rhine River system maintains automated monitoring stations and coordinated flood management across nine countries with different political systems and varying levels of economic development. Both systems function because participating governments recognize a fundamental truth: floodwaters do not respect borders, and flood warnings cannot wait for diplomatic normalization.

Perhaps most instructive for the India-Pakistan context is the Armenia-Türkiye example. Despite having no diplomatic relations and a closed border for several decades, Armenia and Türkiye continue to operate the Arpacay Dam through monthly technical meetings. These sessions maintain equitable water sharing based on agreements dating to 1927. Technical personnel from both countries manage water releases, conduct joint maintenance, and share hydrological data. The system works precisely because it was deliberately insulated from broader political disputes.

The contrast with unilateral action is stark. Ethiopia's construction of the Grand Ethiopian Renaissance Dam on the Blue Nile—without downstream consent from Egypt and Sudan—created permanent regional tensions that persist years after the dam's completion. This is precisely the type of conflict that cooperative management could have prevented or at least mitigated. The lesson for South Asia is clear: technical cooperation on flood forecasting can be separated from broader political disputes if governments choose to do so.

### F. The Cooperation Deficit:

The 1960 Indus Waters Treaty was designed for a different era, primarily addressing water allocation rather than flood management or climate adaptation. While the treaty contains Article VII—specifically designed to address matters of common interest through the Permanent Indus Commission—both parties have systematically failed to invoke this provision for emerging climate challenges.

Article VII provides a clear mechanism for addressing issues of mutual concern, yet neither country has utilized it to establish flood forecasting protocols, glacial lake monitoring systems, or real-time climate data sharing. This failure to operationalize existing treaty provisions represents a deliberate choice to let political paralysis override technical imperatives.
The current reality is stark: Pakistan and India do not share meteorological data in real-time. River flow data arrives, when it does, with 24-48 hour delays—useless for flash flood warnings. There is no coordination on satellite remote sensing interpretation, no joint climate modeling, no shared glacial lake monitoring, no bilateral early warning protocols, and no joint flood forecasting center.

The South Asian Association for Regional Cooperation (SAARC) framework exists but remains dysfunctional. The SAARC Meteorological Research Centre lacks both political support and operational capacity. Proposed agreements on disaster response have never been operationalized. Summit-level politics prevent technical cooperation from advancing. The treaty framework exists—what's missing is the political will to use it.

## The Political Economy Of Institutional Paralysis

Understanding Pakistan's repeated failure to implement flood management reforms requires examining the political economy that sustains institutional paralysis. Technical solutions exist. Scientific knowledge is available. Yet reforms do not happen. Why?

### A. The Governance Architecture:

Pakistan's climate governance architecture encompasses at least six apex councils plus numerous commissions and authorities, yet coordination remains poor. The Council of Common Interests—constitutionally required to meet regularly—convenes far less than mandated. The National Economic Council frequently misses required gatherings. The Pakistan Water Council has met once since 2018.
The National Flood Protection Plan-IV (NFPP-IV) was approved by the Council of Common Interests in May 2017, covering 2015-2025 with an estimated cost of PKR 800 billion (approximately USD 2.87 billion). Following the devastating 2022 floods, the plan was revised in 2024. Despite successive iterations spanning from NFPP-I (1978) through NFPP-IV, key institutional failures have persisted across decades.
Core deficiencies remain unaddressed: inadequate early warning systems, lack of transboundary data sharing, accelerated urban encroachment into floodplains, unchecked deforestation reducing natural water retention, and uncoordinated dam management. Meaningful reforms did not take hold, and the cycle of disaster and inadequate response continued unbroken.

### B. Elite Capture and Incentive Structures:

The Punjab government's decision never to publicly release the full 2010 tribunal report raises a fundamental question: who benefited from keeping these findings hidden? The report identified specific officials responsible for embankment failures, documented illegal encroachments in flood zones, and revealed systematic negligence by irrigation authorities.

Flood plain encroachment represents significant economic interests. Prime riverfront land in cities like Lahore, Multan, and Sukkur has been illegally occupied by commercial developments, luxury housing, and industrial facilities. Enforcing flood plain zoning would require evicting powerful economic actors and politically connected developers.

Similarly, deforestation in northern watersheds continues despite known consequences for water retention capacity. Timber extraction provides lucrative income for local political networks. Forest officials who attempt enforcement face political pressure and security threats. The institutional incentive structure rewards non-enforcement.

District Disaster Management Authorities continue to be absent, dysfunctional, or under-resourced not because of technical gaps but because disaster management competes for resources with politically visible projects like roads and schools. Disaster preparation yields no immediate political returns. Crisis response, by contrast, offers high-visibility opportunities for political credit-claiming through relief distribution.

### C. The India-Pakistan Calculus:

India's concerns about data sharing are not entirely without foundation. Real-time hydrological data could theoretically provide Pakistan with information about Indian dam operations, reservoir levels, and water management strategies. Some Indian security analysts view comprehensive data sharing as potentially providing Pakistan with operational intelligence about infrastructure vulnerabilities.
However, this security framing fundamentally misunderstands what flood forecasting requires. Effective early warning systems need meteorological data (rainfall, temperature, cloud cover) and basic river flow measurements—not detailed dam operation schedules or infrastructure specifications. The Armenia-Türkiye model demonstrates that functional technical cooperation can be structured to address legitimate security concerns while still providing essential flood warning data.

On the Pakistani side, political leaders face domestic costs for appearing conciliatory toward India. Any government proposing expanded cooperation risks accusations of weakness or betrayal of national interests. This political calculation makes technical cooperation hostage to broader bilateral tensions.

The suspension of aspects of the Indus Waters Treaty by India in February 2023 following the Pulwama attack further complicated cooperation prospects. While the treaty's core provisions remain technically in force, the political signal sent by suspension made new cooperation initiatives politically difficult for both governments.

### D. Climate Finance Gaps:

Pakistan's climate finance needs vastly exceed available resources. The 2022 PDNA estimated resilient reconstruction needs at $16.3 billion. Pakistan's draft National Climate Finance Strategy identifies adaptation needs of $348 billion by 2030. Actual climate finance mobilization falls dramatically short.

International climate finance pledges remain largely unfulfilled. Developed countries committed $100 billion annually to developing countries for climate action—a target that was not met until 2022 and remains insufficient for Pakistan's needs. Even when finance is pledged, disbursement is slow, bureaucratic, and often comes as loans rather than grants, adding to Pakistan's debt burden.

Domestically, Pakistan's fiscal constraints limit climate spending. With high debt servicing costs, security expenditures, and competing development priorities, climate adaptation struggles for budgetary priority. Provincial governments, responsible for much disaster management, face even more severe resource constraints.

Innovative financing mechanisms remain underexplored. Parametric insurance that pays out automatically when flood thresholds are reached could provide rapid disaster response funding. Green bonds could mobilize private capital for climate-resilient infrastructure. Debt-for-climate swaps could redirect debt servicing toward adaptation investments. These mechanisms require institutional capacity and international cooperation that Pakistan has not yet developed.

## A Strategic Roadmap

Pakistan's recurring flood disasters demand systematic, phased action. The following roadmap provides concrete steps, organized by timeframe and feasibility, that can break the cycle of crisis repetition.

### A. Immediate Priority Actions:

**First:** Revive the SAARC Meteorological Research Centre with a real operational mandate and adequate funding. The Centre should establish automated weather stations at 50 key locations across South Asia with real-time data sharing protocols. This represents low-political-cost technical cooperation that can build trust for deeper collaboration.

**Second:** Launch a pilot data-sharing project in one sub-basin—either the Chenab or Sutlej—where both countries have strong monitoring infrastructure. This pilot should demonstrate the mutual benefits of cooperation and establish protocols that can be replicated across other basins.

**Third:** Establish a Pakistan Glacial Lake Monitoring Authority with international technical support from institutions like the International Centre for Integrated Mountain Development (ICIMOD). Pakistan has over 7,000 glacial lakes; systematic monitoring of the 100 highest-risk lakes should be undertaken, with early warning systems installed for the 20 most dangerous sites.

**Fourth:** Modernize early warning systems in the 20 most vulnerable districts, with focus on mobile-based alerts that reach vulnerable populations directly. Pakistan's mobile penetration exceeds 80 percent; SMS and app-based flood warnings can provide critical hours of advance notice.

**Fifth:** Enforce mandatory flood plain zoning in all major cities, beginning with Lahore, Karachi, Multan, Sukkur, and Peshawar. This requires political courage but is essential. Illegal encroachments must be removed, with affected parties provided alternative locations or compensation.

### B. Medium-Term Reform:

First: Create a Joint India-Pakistan Flood Forecasting Center, modeled on the Armenia-Türkiye dam management example. The Center should have a narrow, technical mandate: provide 72-hour advance flood warnings for shared river basins. It should be deliberately insulated from broader political disputes and staffed by hydrologists and meteorologists, not diplomats.
Second: Establish binding South Asian data-sharing compacts through SAARC with 90 percent real-time compliance targets. Compliance should be independently monitored with regular public reporting. Non-compliance penalties should be technical (reduced access to regional forecasting systems) rather than political.

**Third:** Update the Indus Waters Treaty, whenever revised, with a climate adaptation protocol that addresses flood forecasting, glacial lake monitoring, and extreme weather coordination. This protocol should be negotiated under Article VII of the treaty, emphasizing continuity rather than renegotiation. International facilitation by neutral technical institutions (World Bank) may be necessary.

**Fourth:** Integrate mandatory climate risk screening into the Planning Commission's project approval process. No infrastructure project above PKR 500 million should be approved without a comprehensive climate vulnerability assessment and adaptation plan. The Planning Commission should publish climate risk assessments for all major projects.

**Fifth:** Establish a South Asia Flood Resilience Fund, pooling $5 billion annually for shared infrastructure and ecosystem restoration. Contributions should be proportional to GDP and historical emissions responsibility. Multilateral development banks (World Bank, Asian Development Bank) should help create such a pool of resources.

**Sixth:** Reform, resource, and empower local government functioning, supported clear mandates, adequate budgets, and accountability mechanisms. Each province should have a functional Provincial Disaster Management Authority with district-level presence in all high-risk districts. Performance metrics should be established and publicly reported.

### C. Long-Term Systemic Change Ambition:

**First:** Develop comprehensive transboundary monitoring systems covering the entire HKH region. This requires sustained international cooperation, significant investment in satellite monitoring and ground-based sensors, and regional coordination mechanisms that transcend bilateral tensions.

**Second:** Scale nature-based solutions to cover 40 percent of flood-prone zones. This includes mangrove restoration in coastal areas, reforestation of northern watersheds, wetland protection and expansion, and river corridor restoration. These solutions provide multiple co-benefits: carbon sequestration, biodiversity protection, and livelihood support alongside flood mitigation.

**Third:** Enforce climate-resilient building codes nationwide. All new construction in flood-prone areas must meet elevated foundation standards, use flood-resistant materials, and incorporate climate-resilient design. Existing critical infrastructure (hospitals, schools, roads and railways, emergency services) should be retrofitted on a priority basis.

**Fourth:** Develop shock-responsive social protection systems covering 60 percent of vulnerable populations. These systems should automatically expand coverage and increase payment levels when disasters strike, providing rapid cash assistance to affected families without requiring new bureaucratic processes.

**Fifth:** Build regional climate cooperation architecture that extends beyond bilateral India-Pakistan relations. South Asian climate challenges require multilateral solutions. SAARC mechanisms should be strengthened and depoliticized, allowing technical cooperation to proceed even when political relations are strained.

### D. Financing the Transition:

The phased implementation requires substantial but achievable financing. Immediate actions require resources primarily for early warning systems, glacial monitoring, and flood plain management. Medium-term reforms require technical and financial resources for institutional development, infrastructure upgrades, and initial resilient reconstruction. Long-term transformation will require substantial resource commitment for climate adaptation and loss and damage.

Domestic revenue mobilization must be prioritized. Pakistan's tax-to-GDP ratio, among the lowest globally, leaves significant fiscal space for improvement. Climate-dedicated revenues could be generated through carbon taxes, flood insurance premiums, and levies on flood-plain development.

International climate finance mechanisms should be fully utilized. Pakistan qualifies for adaptation finance under the Green Climate Fund, Adaptation Fund, and other multilateral mechanisms. These funds remain significantly underutilized due to bureaucratic barriers and inadequate project preparation capacity.

Parametric insurance provides rapid post-disaster financing. When predetermined flood thresholds are reached, insurance pays out automatically without requiring damage assessments. Pakistan should establish sovereign-level parametric flood insurance covering high-risk districts.

Debt-for-climate swaps could redirect a portion of Pakistan's debt servicing toward climate adaptation investments. International creditors have shown willingness to negotiate such swaps when properly structured with transparent governance and measurable adaptation outcomes.

### E. Accountability Mechanisms: Ensuring Implementation

An Independent Climate Adaptation Monitoring Commission should be established with a mandate to track implementation of all reforms. The Commission should have statutory authority, adequate budget, and protection from political interference. Annual parliamentary review with public hearings should examine climate adaptation progress. The National Assembly's Committee on Climate Change should hold hearings where government officials, provincial authorities, and civil society present evidence on implementation progress and explain failures.

Provincial performance scorecards should be developed with standardized metrics: early warning system coverage, disaster management capacity, building code enforcement, nature-based solution implementation, and financial allocation for adaptation. Likewise, civil society oversight is essential. Environmental organizations, community groups, and affected populations must have formal roles in monitoring implementation. Public interest litigation should be facilitated, not obstructed, when adaptation commitments are not met.

## CONCLUSIONS:

Pakistan's flood disasters in 2010, 2022, and 2025 reveal a pattern of institutional failure, unlearned lessons, and systematic non-cooperation that has cost thousands of lives and tens of billions of dollars in economic losses. The solutions are known but what remains absent is the political will to implement what we already understand works.

The scientific evidence is conclusive. Climate change intensified the 2025 monsoon rainfall by 10-15 percent and made such events at least three times more likely. Events that were once rare now occur approximately every five years. Glacial lake outburst risks are escalating as over 7,000 lakes in Pakistan's northern mountains grow larger and more unstable. Compound extremes have become routine. Under current emissions trajectories, these patterns will intensify further.

The transboundary dimensions are quantifiable. Extreme weather events in India cascade downstream into Pakistan with amplified force. Research indicates that functional transboundary cooperation could reduce Pakistani flood damages by 30-50 percent through timely warnings. Analysis suggests adequate early warning systems could have prevented $5-8 billion in economic losses during the 2022 floods alone. The institutional deficits persist. Fifteen years after identifying early warning system failures in 2010, these systems remain inadequate. Real-time data sharing with India is absent. Disaster management coordination across provinces is weak. Infrastructure vulnerability continues unchecked. Glacial lake monitoring is insufficient. Climate finance falls billions short of documented needs.

The 1960 Indus Waters Treaty contains provisions for addressing matters of common interest, yet these have never been invoked for climate adaptation. During the 2025 floods, cloudbursts in Indian Kashmir sent flash floods into Pakistan within 4-6 hours with no advance notification. Pakistani hydrological models underestimated total basin precipitation by 30-40 percent due to lack of rainfall data from Indian meteorological stations. This cooperation deficit is lethal.

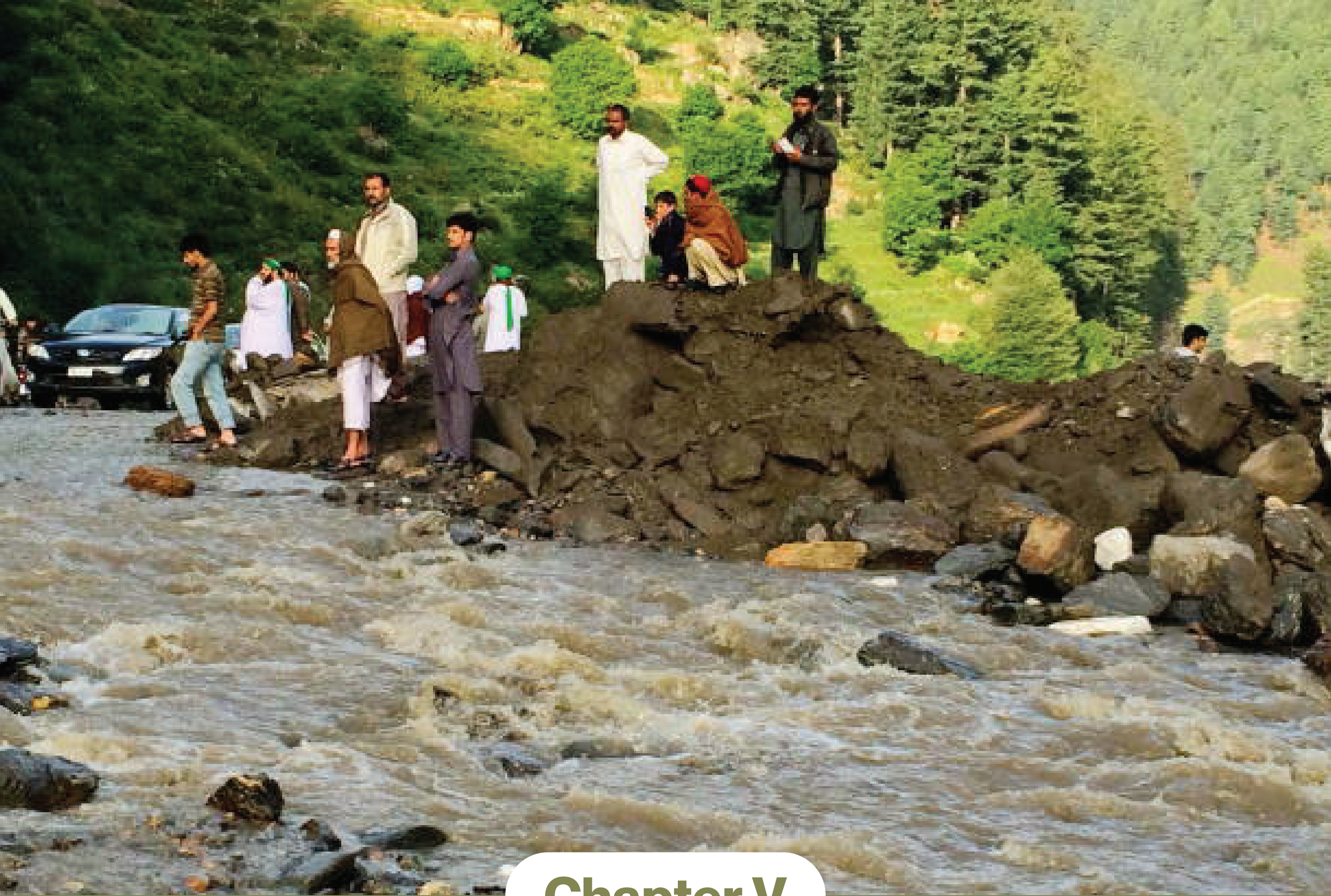
Yet functional transboundary systems demonstrate what is possible. The Armenia-Türkiye water cooperation continues despite no diplomatic relations and a closed border. The Mekong River Commission provides advance warnings across four countries. The Rhine system manages floods across nine nations. These systems work because governments prioritized technical necessity over political symbolism.

The required mechanisms are clear: a joint India-Pakistan flood forecasting center providing 72-hour advance warnings; binding data-sharing compacts with 90 percent real-time compliance targets; coordinated glacial lake monitoring systems; and a South Asia Flood Resilience Fund pooling resources for shared infrastructure and ecosystem restoration.

Implementation depends on political will to separate technical flood forecasting from broader bilateral disputes. The operational question facing both governments is direct: will flood warning systems that save lives be prioritized, or will political tensions maintain a cooperation deficit that measurably increases casualties?

Pakistan's 240 million citizens cannot sustain another decade of repeated institutional failures. The 2025 floods must mark a transition from crisis repetition to systematic reform. The alternative is escalating disasters that will eventually exceed response capacity.

The technical solutions exist. The evidence is documented. What remains absent is the political commitment to implement what we already know works. That choice—between continued paralysis and systematic action—will determine whether Pakistan's next floods are catastrophes or manageable challenges. The time for choosing is now.



Chapter V

# SUSTAINABLE FLOOD MANAGEMENT:

‘Democratic Adaptation is only way forward’

Dr Daanish Mustafa

## Introduction

Most Pakistanis do not realize this, but they live in a vast country. It is the size of Britain and France combined. Pakistan NARC defined 10 agro ecological zones out of the 16 defined by FAO at the time in the 1990s. Today there are 33 recognized agro-ecological zones and the ongoing update of Pakistan's classifications could also perhaps define more.[1]

The point is that the immense geographical diversity of the country means that any attempt at national level, policies to manage hazards are unlikely to be very effective at different local and regional scales, where it actually matters. The alluvial plains of Punjab have very different issues and challenges than highlands of Balochistan, which are very different from the temperate mountains of Kashmir & Hazara, which themselves are very different from the Northern dry mountains of Gilgit and Baltistan. Any attempt at a national level framework needs to be mindful of this diversity and in this chapter, I shall attempt to be as well.

While surveying flood response and long term adjustment strategies by agro-ecological zones is beyond the scope of this chapter, I shall nevertheless attempt to offer solutions which are generically relevant but will need tailoring for specific contexts. I shall also largely focus on the Indus River Basin where almost ninety percent of Pakistan's population is concentrated, with a nod to the issues in the remaining 40% of Pakistan's land area, largely in Balochistan.
The discussion in this chapter on Early Warning Systems (EWS), Infrastructure, Ecosystem Based Solutions (EBS), and Policy and Governance reform will be framed with reference to the following principles:

1. Prioritizing protection of the poor and the most vulnerable.
2. Recognition of differential vulnerability based upon gender, class and ethnicity.
3. Low cost
4. Working with and talking to, instead of working on and talking at, the local people.
5. Ecosystem protection and restoration as a pathway to poverty alleviation and vulnerability reduction.
6. Recognition and protection against cascading and compound hazards
7. Long term adjustment to uncertainty, i.e., how to live with floods by minimising damage from them and maximizing their benefits.

These principles speak to the concern of integrating disaster risk reduction and climate adaptation with longer term developmental visions and practices in Pakistan. Pakistan's present development model steeped in its colonial history and ethos of its elites is dysfunctional. More than 150 years of flood fighting has taught us that every time we fight floods we lose. And occasionally when some societies do win at great expense, they only set themselves up to a worse loss down the road. The Pakistani development model has to move away from its foundational belief in fighting and dominating nature. Instead, it has to recentre its indigenous cultural ethos of living with nature in its developmental visions and practices. It is a tall order, but the discussion in the following sections may provide a starting point.

## Enhancing Early Warning Systems

The flood warning system in Pakistan has considerable room for improvement. It is true that, years of support and efforts towards improving flood forecasting abilities of the Pakistan Meteorological Department (PMD), which is the key government flood forecasting agency, has paid rich dividends in terms of its ability for meteorological modelling and remote sensing of the weather using radars (Awan 2003). The Flood Forecasting Centre of the PMD gets six hourly stream gauge readings of its own. WAPDA's and Irrigation Department's networks also provide readings which can be increased to every half hour in an emergency. The mode of collection and conveyance of data, nevertheless is highly unreliable. The data collection is mostly visual gauge readings, and conveyance is through police wireless. The data is also certainly not real time, for input into the flood models (Awan et al. 2025, Awan 2003, PMD 2019). The major bottlenecks in the Pakistani flood warning structure are:

1. Limited number of weather stations and lack of concurrent stream gauge data. The PMD has only 100 manual and 30 automated weather stations in all of Pakistan.
2. Constricted filtering down of the flood warnings to non-governmental end users, especially the communities actually exposed to flooding, in a timely manner.
3. Inability to convey warning in non-jargonistic vernacular languages, which are actionable.
4. Lack of knowledge and trust in the end user communities in the flood warning.

1 https://data.apps.fao.org/catalog/iso/0bd6eef3-009c-43d5-b846-952366df8da9

The PMD has provincial offices, which have to obtain authorization from the Director General PMD to issue extreme weather warnings to government agencies. Other researchers have also stressed the need for regional/ provincial flood warning centres so as to provide timely warning to local authorities for flash flooding and regional flooding, beyond the main stem river flooding.[2] In view of the above the possible pathways to improved EWS will be elaborated upon in the following sections on Meteorological Monitoring, Community Based EWS and Integration with Disaster Response Mechanisms.

## 1. Improved Meteorological & Hydrological Monitoring:

For improved meteorological monitoring, the PMD in the first instance has to thicken its network of weather stations of 130. In Nepal, which is less than half the size of Pakistan there are 387 weather stations. Pakistan is undertaking a welcome investment in installing 300 additional automated weather stations.[3] One hopes that that investment will bear fruit and the stations will be installed in good time and maintained. For pluvial floods and flash floods, enhancement in the data collection network is likely to be quite helpful. Nevertheless, given the mountainous topography of much of Pakistan there is a need to thicken the network further, especially in Balochistan, particularly since there are numerous local weather patterns that are missed by the monitoring stations, and it is not entirely clear where the new automated stations will be installed.

It will be perhaps beyond the capacity of any meteorological department to monitor every single watershed or local weather pattern. Which is where the PMD needs to rethink its model of centralized data management and processing and decentralize. A basic weather station has the following components: thermometer, barometer, hygrometer, anemometer and a rain gauge. Each of these components can be procured for a minimal cost, though automated weather stations with all of the above components with the ability to transmit real time data can be acquired for anywhere between US $ 300-500.

- **Recommendation:** Support and provide technical assistance to install weather stations on the premises of schools, colleges or any other government installation.

The Citizen Weather Observer Programme in the United States is an example of involving citizens in observing the weather.

- **Recommendation:** Encourage amateur and interested citizens to install weather stations on their premises and integrate the results into the national data stream. Provide them technical assistance and quality control.

In terms of alluvial floods in the Indus basin, there are multiple agencies operating stream gauges, mainly the Water and Power Development Authority (WAPDA), followed by provincial irrigation departments, PCRWR and PMD. Being that most of the stream gauges are manual the timeliness of the readings and conveyance of the same is a question. The height readings that are taken routinely at gauges under bridges or irrigation infrastructure have specific empirically derived quotients to convert height into volumetric flows. Those quotients are typically out of date and not well understood.[4]

- **Recommendations:** Update the volumetric flow conversion quotients for the installed stream gauges.
- Overcome political and bureaucratic opposition to install (restore) telemetric systems.
- Make the readings available to the public in real time on the web, as was done in the 1990s and 2000s.

The PMD radar network is legitimately directed towards monitoring the headwaters of the Indus river system, but that network could be intensified. However, attention to investing in radar infrastructure in population centres which may be vulnerable to hill torrents, e.g., DG Khan or coastal flooding, e.g., Gwadar, Karachi & Badin, could be a wise investment.

Overall though the quality of modelling and hydro-meteorological data collection and processing is the least of Pakistan's problems. The main problems are the dissemination and credibility, as well as the risk knowledge and response capacity of the recipients. I turn to the dissemination, credibility and risk knowledge aspects of EWS below.

### 1.2 Decentralized, Community-based early warning systems:

At the moment only DG PMD is allowed to authorize issuance of flood or extreme event warning. If the DG is unavailable the official warning will have to wait. Similarly, the flow of warning is from federal to provincial down to the government hierarchy to the local level, where it really depends upon the local administration how effectively they disseminate the warning to the local populace. There I recommend the following:

- Decentralize issuance of pluvial flood warning to the regional PMD offices, preferably at the district level.
- Decentralize fluvial flood warning in minor river channels and flash flooding to the regional and local scale.
- Decentralize fluvial flood warning in major rivers to at least the provincial scale.
  - Real time data and information sharing between federal and at least provincial PMD offices should ensure accuracy and quality of the warning at those scales.
- Instead of relying upon antiquated communication through fax, telephone, or email, down the government hierarchy, phone companies should be inducted to provide localized/regional warning

2 A_critical_analysis_of_2010_floods_in_Pakistan
3 https://www.arabnews.com/node/2572940/pakistan
4 https://rgs-ibg.onlinelibrary.wiley.com/doi/abs/10.1111/tran.12169

(SMS) messages in vernacular languages directly to the local communities. There is no reason why a Deputy or assistant commissioner must know about an impending flood before vulnerable communities. They could find out at the same time as everyone else.

Effective dissemination/communication of early warning helps, but it cannot help much if people do not believe or understand the warning. People's trust cannot be commanded, it has to be earned. In the first instance public education about the existence of the warning system and its channels need to be a priority. If the channel is going to be a mosque/church/temple then so be it. Or if it is a local councillor (which mostly don't exist) or the corner Easypaisa shop or patwari/lumberdar then, that is fine too. And if it will be a mobile phone, or the combination of the above then they need to be made aware of it. But in that awareness campaign it must be kept in mind the gendered access to information from various sources. Mosques are men's terrain. Women may access different sources of information that should be borne in mind and those information channels should be utilized. Village midwives or health workers, for example, could be given mobile phones and made into emergency wardens to disseminate information to women where they may not have access to other sources, especially in rural areas.

Lastly, the above recommendation of encouraging citizen data collection and installing and supporting installation of basic weather stations in schools and colleges could help with risk knowledge. In particular for women, girls' schools as sites for such stations should be made a priority. Children and adults who can see how information is gathered and have a feeling of participating in contributing to the EWS are likely to give greater credence to the same and act on it to save lives. In that vein, reintroduction of disciplines like Geography and basic sciences at the school level will go a long way towards improving risk knowledge of the communities and hence their behaviour in the face of floods.

## 1.3 Integration with disaster response mechanisms

One of the Achilles heels of even the most accurate, accessible and credible EWS is that they're not actionable. This situation arises on the one hand from the: (1) overly technical focus, (2) language of delivery and, (3) lack of a link between early warning and differential ability to act. I tackle each of these aspects in this section.

First, the articulation of early warning in terms of millimetres of rain or cubic feet per second (cusec) of volumetric flows mean nothing to the general population and often even to experts. A certain millimetres of rain may cause catastrophic flooding in Kharan, or Kech Balochistan, but may be just an average rainfall in Murree and Azad Kashmir. A certain cusecs of water flow in the Indus mainstem near D. I. Khan may be unremarkable, but may constitute high flood in the Sutluj near Suleimanki.

The PMD along with WAPDA at the federal level in coordination with provincial irrigation departments should develop a typology of low, medium, high to very high risk rainfall and flow categorization by agro-ecological zones. These categorizations could then be further refined and nuanced at the district level to provide meaningful warning to the local population.

The categorization referred to above could then become the basis for public education with a set of actions associated with each, e.g.

- **Low flood/rainfall:** Avoid river banks, secure belongings, look out for loose electric wiring.
- **Medium flood:** No fishing, swimming, move possessions and animals to higher ground, beware of snakes.
- **High flood:** evacuate flood plain, move animals and children to higher ground, undertake flood protection protocols.
- **Very High flood:** mandatory evacuations in inundation zones, move to flood shelter, red alert.

The above are just examples, I am sure they could be refined with greater local knowledge. The point is that such a schema will need to be widely disseminated, and public educated on what to do when the warning is issued, prior to the event. These could also be part of the school curriculums.

Secondly, Pakistan needs to dispense with the colonial habit of issuing warnings in English or at best in Urdu. Pakistan is a multi-lingual country and early warning should not be a platform for establishing colonial privilege through English, or Nation building through Urdu. Instead, all regional offices should issue warnings in vernacular so that they are understandable to the general public, especially women in rural areas who only speak the local languages, like Sindhi, Brahvi, Shina, Punjabi or Kohistani for example.

Lastly, an effective EWS has to be linked to the vulnerability profile of the population exposed to the hazard. Towards that end, I have proposed it before and I can propose here that provincial Revenue Departments can be at the forefront of undertaking simple vulnerability assessments for the communities. Revenue Departments because they have the deepest penetration of any state agency in the country, with the possible exception nowadays of the federal intelligence agencies. The Patwari is the lowest rung of the government bureaucracy, and whereas in the past they used to maintain land records and assess crops for revenue, nowadays almost none of their traditional functions are very relevant. These functionaries could be repurposed and retrained to undertake periodic vulnerability

assessments using simple vulnerability assessment tools. For an example of such tools please see the Vulnerability and Capacity Index.[5]

5 https://onlinelibrary.wiley.com/doi/10.1111/j.1467-7717.2010.01193.x

Just as in the case of Hurricane Katrina in the US, assumptions about a universal ability to act or to evacuate must be re-evaluated. Women have limited mobility. Rural households would not evacuate without their livestock, in fact they would prioritize livestock over everything else. Poor people and women in places distant from main communication arteries are often disadvantaged in terms of accessing relief. Having vulnerability profiles in hand, and understanding local political economic and gender dynamics, will facilitate more targeted action. If flood shelters are to be built in certain areas, as they should be, there should be provision for animal shelters besides the ones for humans so that people can use them. But such knowledge can only come if the vulnerability profile is known. And hence the importance of vulnerability profiling prior to disasters cannot be over emphasized.

### 2. Improving Resilience Infrastructure Development and Maintenance

Pakistan, true to its colonial flood management heritage, is obsessed with flood fighting. And the main weapon deployed in that 'battle' against floods are levees, spurs and dams. Even if two hundred years of flood fighting has taught us anything, it is that every time one fights floods, one loses. But that history doesn't seem to matter, and every flood season is about strategically doing the same. Granted, however, that flood protection is essential to protect essential and sensitive infrastructure, but the use of levees, bunds and spurs should be judicious and not indiscriminate modes of patronage, as is the case right now.

Certain urban areas should be protected, but all these protection measures do is transfer the problem to the opposite bank of the river or downstream. Therefore, any use of flood protection bunds should be accompanied by restoration of wetlands, upstream and downstream of the bunds to mitigate flood peaks. Such restoration of wetlands could prioritise the twenty three designated flood inundation zones upstream of the barrages, where the right bank bunds are frequently breached to protect the barrages. The residents of these inundation zones could be fairly compensated and/or provided support to flood proof their housing through traditional measures like building on higher platforms or with techniques like building on stilts. Similarly, they could be provided support to switch to flood resistant crops or flood farming—livelihoods that are more resistant to flood peaks. The ecosystem services that wetlands provide including groundwater recharge, biodiversity, water purification, carbon sequestration and flood peak mitigation makes them an invaluable tool in flood management which hasn't been used much in Pakistan.

Floodplain reconnection, wetland restoration and ecosystem recovery in the Yellow River area

Flood plain reconnection, wetland restoration and ecosystem recovery in the Mekong River area

## 2.1 Drainage

One of the best known secrets of flood mitigation is about drainage. The damage caused by inundation itself pales in comparison to the damage caused to human life and health by stagnant waters and the displacement and diseases they cause in the aftermath of the floods. In fact, inundation itself is partially a function of lack of drainage. A lot of infrastructure has been built in flood plains, e.g., canals, roads, railway lines and levees etc. which serve as dams against the natural flow of water back into the river channel.

Provision needs to be made to allow drainage through such infrastructure by provision of culverts under roads and railway lines, to allow the water to drain. Similarly, local communities need to be consulted in such drainage projects to use their knowledge to facilitate natural drainage instead of expensive engineering studies. The Pakistani water establishment is as eager to blow up levees to flood communities and protect infrastructure, as it is shy to breach levees to allow drainage to help the same communities. That pattern of behaviour needs to change. Lives and livelihoods of the people of Pakistan need to be valued more if not as much as the concrete irrigation infrastructure

In some instances however, it might be too expensive or difficult to open up natural drainage. In those instances, high capacity pumps should be made available to Public Health Engineering, WASA and/or to local administration to episodically help drain pools of water in certain locations.

Urban drainage requires massive investments, but beyond that, the political will to control land use and allocate resources for unglamorous urban drainage projects. There's a saying that the best infrastructure is unseen—something that is anathema to the Pakistani politico-military elites. Urban wetlands, green spaces and drainage conduits could serve as flood protection as well as groundwater recharging pathways. Something that should be prioritized in urban design, instead of the disastrous automobile dependent urban design paradigm that the country is locked into.

## 2.2 Flood Plain Management:

Flood plains cannot and should not be made devoid of any human use. The challenge is to encourage wise flood plain use. In that vein, housing societies, and polluting industries should be discouraged if not banned from the flood plains. However, building of river parks, agro-forestry, and even school and ware houses could be reasonable uses of the flood plains. Schools need space and can be easily evacuated. Warehouses may lose material but at least human life will not be put in peril. Even human habitation with appropriate architectural modifications, e.g., stilts and elevated plinths would be reasonable uses of the flood plain. Any agricultural use is also reasonable as long as proportionate to risk insurance is obtained for such activity.

Encroachment on River Ravi created flooding in the housing societies around Lahore

Inundation of Housing societies in Lahore

### 2.3 Attention to Cascading and Compound Hazards from Floods:

One of the biggest blind spots in Pakistani disaster management, besides its reactive ethos, is lack of understanding and recognition of compound and cascading hazards. Compound hazards are multiple hazards that occur simultaneously or in succession, leading to more severe impact than if they were to occur individually.

Cascading hazards as the name indicates are hazards that are triggered from the initial hazard, flooding in our case, leading to more severe and widespread impacts than the initial events.[6] Examples of compound hazards in case of mountainous Pakistan could be intense rain accompanied by landslides and mass wasting.

6 https://www.nature.com/articles/s44304-025-00111-5

Rain itself can impact unsafe housing, while the landslides that accompany such events could disrupt communications and in the long run food security as a cascading hazard. Longer term measures to address such compound hazards could be slope stabilization and strong controls on construction on mountain slopes and near stream channels.

Some of the hazard cascades from urban flooding may be the following:
Urban pluvial flooding → solid waste swept into drains and homes → sewerage overflow from blocked drains contamination of ground & water → disease
Urban pluvial flooding → fragile electric infrastructure compromised → electrocution & death

The above two cascades are illustrative, but they highlight the necessity of maintaining storm drains in urban areas, and reinforcing electricity infrastructure to prevent electrocution. In Karachi in 2019 for example, of the 17 people killed on August, 11th, 2019, 7 died of electrocution and three from roof collapse. Equally, the above urban cascades illustrate that floods cannot be managed episodically, nor should they be thought of in that register. They are developmental failures. Lack of solid and liquid waste management or fragile electricity infrastructure are developmental failures that become amplified by floods. Flood management cannot and must not be thought of in isolation of routine municipal functions of infrastructure maintenance, and solid and liquid waste management.

In the rural areas the hazard cascades are likely to be different, for example:
Rural alluvial flooding → wide spread inundation → snakes and people move to higher ground → snake bites and death.
Rural alluvial flooding → wide spread inundation → lack of timely drainage → chemical & fertilizer contamination → mosquito breeding → fecal contamination of water → death and disease.

Again, the above cascades illustrate for example, the urgent need for upgrading rural health infrastructure. Snake bites for example, are generally the second if not the first biggest cause of fatalities during flood events in Asia and Africa.[7] The government of Nepal for example has national guidelines for snake bite management, there is no reason why Pakistan could not have such guidelines nationally or at least provincially. Public education about snakes and training to provide first aid, along with provision of anti-venom to local health workers could go a long way towards saving lives.

Similarly, provision of water purification tablets during and after floods and prioritization of drainage could mitigate the second example of rural hazard cascade above. But more than that these cascades are illustrative of developmental failures and Pakistan's wholesale reliance on green revolution technologies and embrace of corporate agriculture. A critique of those could be the subject of many other reports, but recognition here, could possibly provide pathways for different development trajectories and a safer present and future for the people of Pakistan.

## 2.4 Policy and Governance Reforms

Institutional and governance reforms in the first instance have to be predicated upon human resource development. One of the most glaring gaps in an otherwise glowing constellation of water experts in Pakistan are expertise in process geomorphology and hydrology. Most Pakistani water managers are either trained civil engineers or social scientists with experiential training on water issues. There is very anaemic expertise on water from a purely scientific perspective.

In Pakistan where rivers have some of the highest silt loads in the world, to simply think of them in terms of water flows and control structures is a folly. Basin geomorphological and hydrological research in Pakistan could not only enhance understanding of the great Pakistani rivers' natural behaviour, but also help design more secure control infrastructure and manage floods. Beyond the human resources there could be an infinite number of specific institutional reform proposals that could be considered at the federal, provincial and local levels. A few of them in the context of PMD have already been alluded to above. In this section however, I will focus on structural reforms consistent with the principles of sound flood management outlined in the introduction to this chapter.

The Pakistani state has always held close its colonial ethos that drive its impulses towards centralization and rule by fiat. It is a small surprise that political parties mimic that state impulse by encouraging patronage based politics. Accountability to the rank and file through elected and empowered local government structures is anathema to the political parties. Military governments tend to promote them for the wrong reasons, i.e. to depoliticise the polity, which again fails. Meaningful vulnerability reduction and place based flood management and recovery will be impossible in the absence of elected and accountable local government structures. But they are not on the horizon. While decentralization and empowering local leadership who know their areas is imperative, the Pakistani state is in fact, moving in exactly the opposite direction. A visit to any Deputy or Assistant Commissioner's office in Pakistan and looking at the obligatory list of their predecessors behind their desks will illustrate that the average tenure of these officers in each district ends up being less than a year with some in place for less than three months. Such short tenures and rotations make it impossible for these officials to get to know the people, let alone geography of their jurisdictions. Such a situation is not helped by the imperious ethos of the Pakistani civil service to begin with.

Any meaningful adjustment to flood hazard in Pakistan will have to start with the creation and empowering of local government in Pakistan. Such local representatives will be closer to the people and be more accountable, in addition to bringing valuable local knowledge to flood management. Rescue 1122 and private initiatives like Edhi and CHIPPA are good and effective. They have to

7 https://www.etvbharat.com/en/!bharat/monsoon-mayhem-in-india-floods-bring-snakes-closer-to-human-settlements-enn25062106505

be linked into a local ecosystem of governance that can direct their resources as needed, for them to be more effective.

The federal and provincial governments can mandate guidelines for flood plain management, but they cannot be competent implementers of those guidelines, as the pretense seems to be at present. Organizations like NDMA and Climate Ministries may be appropriate for liaising with international donors, which is about all that they do at present. But given the geo-economic changes in the world bilateral and in the medium term multi-lateral, donors are going to be less significant in the financing picture for the global South. The Climate Change Ministry, NDMA and Federal Flood Commission could be retained for training, and harvesting of international best practices, but their efficacy to actually do anything will always be limited, not just constitutionally but just by virtue of the geographical diversity of Pakistan. The solution going forward is in decentralization and not centralization.

## 2.5 Conclusion

Floods have become a major hazard threatening the lives and livelihoods of the people of Pakistan, but they don't have to be. Pakistan would not exist without the life-giving flood pulses of the Indus River system and other streams. The silt they bring from the Himalayas have built the fertile alluvial plains that support some of the highest population densities in the world. For millennia, the society of present day Pakistan lived with the floods, celebrated their arrival and benefitted from the bounty they left behind. The problem started in colonial times and 150 years ago a blessing turned into a hazard.  Not because the rivers changed, but because the society changed. It decided to fight and control the rivers instead of living with them. And the rivers and monsoons fought back. We should not be surprised that we are losing in that fight. Prudence would dictate that we not fight, and the recommendations in this chapter are premised upon that insight.

Giving rivers room to flow, having effective early warning systems, facilitating flood resistant urban and habitation design, decentralization of flood governance, attending to drainage, appropriate flood plain use, and attending to drivers of hazard cascades are key to effective flood management in Pakistan. Climate adaptation is often touted as a panacea, except that no one can really define what that means beyond the platitudes handed down by the IPCC or international donors and researchers. Effective vulnerability mitigation and pro-poor and gender sensitive development in the here and now are not separate from climate adaptation, in fact they are foundational to it. Hopefully this chapter has outlined some pathways to realizing a more climate adjusted Pakistan.

8 https://www.youtube.com/watch?v=3bVGuXrd5mg

Chapter VI

# COMMUNITY-BASED DISASTER RISK MANAGEMENT (CBDRM)

Noreen Haider

## Introduction

The term Community-Based Disaster Risk Management generally encompasses a similar definition to DRM but is particularly relevant to, or has a focus on, the community level. Community participation at many stages and levels is the central component of CBDRM initiatives. There are numerous definitions of CBDRM but according to the definition of the Asian Disaster Preparedness Centre (ADPC) "Community-based Disaster Risk Management (CBDRM) is a process in which at-risk communities are actively engaged in the identification, analysis, treatment, monitoring and evaluation of disaster risks in order to reduce their vulnerabilities and enhance their capacities."

CBDRM has to be grounded not only in comprehensive disaster (risk) management principles—encompassing risk assessment, mitigation, preparedness, response, and rehabilitation—but also in the application and adaptation of indigenous, localized risk-coping knowledge for risk reduction purposes.

In Pakistan where there are far flung and hard to reach mountainous regions which are susceptible to natural hazards including flash floods and earthquakes or small fishing villages in the coastal areas at risk from hurricanes, it is vitally important that local communities are trained for CBDRM and each village vulnerable to any natural hazard has a plan for effective risk management at the local level.

## The Risks in the Hindukush/Himalayas

The HinduKush/Himalayan (HKH) region is characterized by dramatic and challenging geography. As the world's youngest mountain system, it suffers from unstable geological conditions and steep terrain. When combined with frequent extreme weather, this makes the area highly susceptible to various natural hazards, including landslides, avalanches, earthquakes, massive snowfall, and flooding. Of these, flash floods present a particularly severe threat to local communities during the monsoons.

Flash floods are sudden, severe flood events that offer little to no warning. They can be triggered by intense rainfall, the failure of natural or artificial dams, or the outburst of glacial lakes. In the HKH region, the frequent occurrence of flash floods poses a significant danger to lives, livelihoods, and essential infrastructure, both within the mountains and in downstream areas. Vulnerable groups, such as the poor, women, children, and people with disabilities, are often the hardest hit.

Flash floods are more destructive to human life and livelihoods than regular riverine floods, which develop over a period of days following heavy upstream rainfall. Due to the higher volume of debris they carry, flash floods inflict greater damage on hydropower stations, roads, bridges, buildings, and other infrastructure. Historically, efforts to mitigate flood hazards have relied on structural measures and centralized control, leaving little involvement for the exposed communities.

The remote and isolated catchments where most flash floods occur often lack consistent government presence. When a flash flood strikes, external assistance can be delayed for days, leaving affected communities to manage the crisis independently.

Building community capacity for self-management is crucial for mitigating flash floods and other disaster risks. Although individual households currently undertake some risk management, coordinating these efforts through a unified local structure, such as a Community Rescue Committee is needed to enhance its overall effectiveness.

Communities are strongly motivated to execute effective disaster avoidance activities, given their direct stake in their own survival and well-being. Therefore, training and mobilizing them in a manner and language that is easily understood at the local level is not a difficult task.

### Disaster Preparedness

Every monsoon season, the mountainous districts of Khyber Pakhtunkhwa (KPK) experience a dangerous combination of extreme rainfall, cloudbursts, and river surges that routinely trigger landslides, mudslides, and sudden flash floods. These hazards strike with little warning, often cutting off roads and blocking access routes, making it extremely difficult for provincial rescue agencies or emergency teams to reach affected communities in time.

In such terrain, after any unexpected disaster, the true first responders are almost always the local residents themselves—families, neighbours, and volunteers who act within the first critical minutes when survival is still possible. This reality underscores the urgent need for systematic community based disaster management.

Effective community-based disaster preparedness hinges on three key areas: awareness raising on disaster risk reduction and preparedness, comprehensive training and adequate resourcing.

**Awareness Raising:** A key component of Community-Based Disaster Risk Management (CBDRM) is raising community awareness and education regarding local hazards. This includes understanding potential threats like flood zones and landslide risks, recognizing natural early warning signs, and learning about climate change and the necessary adaptation strategies to manage its impacts.

**Training and Capacity Building:** The second component is training for a selected group of community members. This should cover critical skills such as swimming proficiency, basic diving techniques, safe evacuation methods, first aid, CPR, and reliable emergency communication protocols.

**Essential Life-Saving Resources:** The third component is that all communities vulnerable to any risk, down to the villages level, must maintain a ready inventory of basic life-saving equipment. This essential gear—including first aid kits, ropes, ladders, life jackets, throwbags, whistles, torches and vital medicines—can significantly improve the chances of saving lives in the critical period before formal emergency responders are able to arrive.

## CBDRM Saves Lives

International best practices strongly support this model of CBDRM. In Bangladesh, trained cyclone preparedness volunteers have reduced cyclone mortality by over 90% since the 1970s; in Nepal, community-led search-and-rescue teams have been instrumental in saving lives during earthquake-triggered landslides; and in the Philippines, barangay-level disaster brigades are credited with rapid evacuations that have consistently lowered casualties during typhoons and flash floods. These examples demonstrate that empowering local communities is not optional but is the most reliable, impactful, and life-saving strategy in hazard-prone mountain regions like KPK.

Successful Models from the region include:

- **Cyclone Preparedness Programme (CPP), Bangladesh during Cyclone Bulbul (2019)**
  In November 2019, when Cyclone Bulbul threatened coastal Bangladesh, some 6,000 trained CPP volunteers,many of them women, sprang into action. They disseminated early-warning messages, went door-to-door to evacuate people to safe shelters, and helped vulnerable groups (women, children, elderly) reach safety.[1]
  Their rapid mobilization significantly reduced casualties by enabling timely evacuation and sheltering.

- **CPP & community volunteers during Cyclone Fani (2019)**
  In another case, 600 trained volunteers under CPP (some supported by United Nations Development Programme (UNDP)'s adaptation programme) helped disseminate cyclone warnings, guide evacuations, and coordinate shelter occupancy — reducing loss of life and enabling safer evacuation for at-risk coastal communities.

- **Village-level resilience building in Bangladesh's flood-prone Patuakhali district (2013–2016)**
  In coastal villages of Patuakhali district (areas such as Pashurbunia and Nowapara), local communities participating in a resilience-building programme installed flood-resistant wells, raised latrines above expected flood levels, and adopted safer building practices. As part of the initiative, they received training in early warning, hygiene, first aid, and community-level adaptation. This community-based intervention improved survival and reduced health and livelihood impacts when floods and storms struck.[2]

- **Community-led aid & rescue in remote regions of Nepal after the 2015 earthquake**
  After the catastrophic 2015 earthquake in Nepal, when official aid faced delays and many remote villages remained inaccessible due to damaged roads and landslides, grassroots networks and local volunteers stepped in. One well-known example is a grassroots group dubbed The Yellow House (Kathmandu-based), which quickly mobilized 170+ rescue and relief missions, distributing food, medical supplies, tarpaulins, organizing evacuations, and even coordinating private medevacs for seriously injured people. Their rapid, locally organized action saved lives at a time when formal relief was slow to reach remote communities.[3]

- **Mountain-biker network in Nepal rescuing quake-isolated villages (2015)**
  In the immediate aftermath of the 2015 earthquake, Nepal's mountain-biking community — using their knowledge of terrain, mobility and endurance — delivered emergency supplies (food, medicines, hygiene kits) to remote villages cut off by landslides and damaged infrastructure. Their efforts reached communities that were unreachable by vehicles, preventing starvation, dehydration, and further casualties.[4]

1 https://www.undp.org/bangladesh/stories/volunteers-protect-community-impact-cyclone-bulbul
2 https://www.ucl.ac.uk/news/2020/jun/analysis-bangladesh-has-saved-thousands-lives-devastating
3 https://www.wired.com/2015/05/nepal-earthquake-aid
4 https://time.com/3848077/nepal-earthquake-mountain-bike-cyclist-ride-to-rescue-aid-relief

## Strengths of Community-Based Disaster Response

**Speed & local knowledge:** Because community volunteers live nearby and know the terrain, they can respond quicker than national or external agencies — a critical factor when disasters strike suddenly.

**Trust and social cohesion:** Local first-responders are trusted by their communities, which helps in convincing people to evacuate, follow warnings, and coordinate effectively. In most communities in the Khyber Pakhtunkhaw district in Pakistan, where women traditionally wear veils and observe pardah they would not be comfortable to be rescued by strangers in even extreme risk prone situations.

**Context-appropriate solutions:** Communities understand local vulnerabilities (flood-prone areas, weak housing, accessible shelter points) and can adapt warnings and responses accordingly.

**Flexibility and adaptation:** When formal systems fail (roads blocked, remote access lost), community responders adapt — using bikes, boats, local shelters — to ensure aid reaches people.

### State of Community-Based Disaster Risk Management (CBDRM) in Pakistan

Community-Based Disaster Risk Management (CBDRM) in Pakistan exists largely in fragmented, project-based forms rather than as an institutionalized, nationwide system. While Pakistan has a comprehensive legal and policy framework—anchored in the National Disaster Management Act (2010), the National Disaster Management Plan (2012–2022), and subsequent provincial policies—implementation on the ground remains uneven, underfunded, and inconsistently supported across provinces.

Although CBDRM is recognized as a critical component of Pakistan's disaster management architecture, the structures envisioned at the village, union council, and district levels—such as Village Disaster Management Committees (VDMCs) and Community Emergency Response Teams (CERTs)—are not systematically established.

Most functioning CBDRM units were created through time-bound, donor-funded interventions led by UNDP, USAID, GIZ, Oxfam, ACTED, and various INGOs. These initiatives trained community volunteers in early warning, first aid, evacuation, hazard mapping, and local preparedness, especially in hazard-prone districts of Khyber Pakhtunkhwa, Punjab, Sindh, and Balochistan. However, once project funding ended, the majority of committees became dormant due to the absence of government financing, sustained capacity-building programs, and integration with provincial disaster management authorities.

Punjab with the Rescue 1122 system stands out as the only province with a relatively structured and ongoing Community Safety program, established under section 5(g) of Punjab Emergency Service Act, 2006 , where Community Emergency Response Teams continue to receive basic life support, evacuation, and rescue training.[5]

In contrast, CBDRM efforts in KP, Sindh, and Balochistan are dispersed, short-lived, and highly dependent on the presence of NGOs. In high-risk mountainous areas—such as Chitral, Swat, Kohistan, and Gilgit-Baltistan—local communities often become de facto first responders due to delayed access for formal emergency services, yet they typically lack the necessary equipment, training, and formal coordination mechanisms.

The absence of institutionalized CBDRM has resulted in critical gaps in disaster preparedness, early warning dissemination, and community-level response capacity. Most villages lack trained volunteers in swimming, rope rescue, first aid, CPR, or evacuation procedures, and communities seldom have access to life-saving equipment such as life jackets, ladders, rescue ropes, radios, or community-held boats. As a result, Pakistan's most frequent and deadly hazards—flash floods, landslides, glacial lake outburst floods (GLOFs), riverine floods, and urban flooding—continue to cause disproportionate loss of life, particularly in remote and mountainous regions.

Although the National Disaster Management Ordinance 2006 provides the legal basis for national, provincial, and district-level disaster management bodies, its operationalization remains weak and inconsistent. CBDRM in Pakistan is characterized by isolated pockets of success rather than a cohesive national system.[6 7] Without formal recognition, sustained funding, capacity-building programs, and integration of community responders into the provincial and national disaster management framework, communities will continue to serve as first responders in practice—yet without the skills, tools, and institutional support required to save lives effectively.

## Strengths of Community-Based Disaster Response

On 27th of June 2025 in a tragic incident in River Swat, at Khwazakhela, a tourist family got caught in a sudden flash flood while they were taking photos, standing inside the river, unaware of any impending danger. The

5 https://www.rescue.gov.pk/csafety.aspx#:~:text=Rescue%201122%20is%20not%20just,for%20enforcement%20of%20preventive%20measures.
6 https://www.preventionweb.net/news/pakistan-community-based-disaster-risk-management
7 https://reliefweb.int/report/pakistan/pakistan-community-based-disaster-risk-management-and-school-safety-programmes

water suddenly started to rise sharply and they were caught, off guard, in a massive flash flood. As they realized the danger, they barely managed to scramble on a rock inside the river and within minutes, were completely surrounded by the gushing flood water. Although the stranded family was only just a few meters inside the river yet they could not possibly make it across the river to safety. Thirteen members of the same family kept hanging on the slippery rock for more than an hour, holding on to each other, shouting and pleading for help but the ferocious flood did not allow anyone close by to get to them.

There were scores of onlookers, mostly locals, on the river bank who were forced to watch in distress as the tragedy unfolded. Despite their presence, they were helpless, as they neither had the necessary skills to navigate the fast flowing water nor any basic equipment like ropes, old tyres or life jackets that they could have used in an attempt to rescue the struggling victims.

One by one the victims slipped and fell into the river and were instantly washed away by the strong currents of the river. Tragically, ten members of the same family, including women and children, were among the thirteen people who drowned in the Swat River that day.[8]

The rescue 1122 KPK team arrived after the critical delay of one hour and even it did not have the requisite equipment or enough trained manpower to take any effective rescue action in the shortest time.

Thirteen victims swept away by the flash floods in river Swat at Khwazakhekla on June 27 2025[9]

The swat river tragedy shocked the entire nation and starkly revealed the unpreparedness and vulnerability of the local communities in case of any emergency.

State of the Rescue 1122 KPK during the river Swat tragedy[10 11]

8 https://tribune.com.pk/story/2553090/19-swept-away-as-swat-river-surges-dangerously-after-heavy-rain
9 https://www.geo.tv/latest/611191-five-bodies-recovered-after-18-members-of-same-family-swept-away-in-swat-river
10 https://tribune.com.pk/story/2553090/19-swept-away-as-swat-river-surges-dangerously-after-heavy-rains
11 https://www.dawn.com/news/1920812/tarar-assails-kp-administration-as-11-bodies-recovered-from-swat-river

The three-member official inquiry committee constituted by CM KPK, in its investigation report later described the situation as "a race against time," where every minute mattered.'The local administration and emergency services were neither equipped nor adequately trained to handle water-related emergencies'.[12] The committee's 63-page report—based on eyewitness accounts, official statements, survivor testimonies, and even WhatsApp message logs—details systemic failures at multiple levels, including weak disaster preparedness, poor regulatory oversight, and widespread negligence.

The fact that makes it even more horrifying is that the tragedy was completely preventable. The Pakistan Meteorological Department had provided timely warnings of potential flash floods in the upper Swat region due to heavy monsoon rains. Despite this clear and present danger, the district administration failed to take any necessary preventive measures. They did not issue safety advisories, restrict movement along the riverbanks, or put up even a single warning sign. Tourist activities were allowed to continue without restriction as business as usual. The inquiry concluded that this complete inaction was the direct cause of the high death toll.

The Swat tragedy also highlighted the fact that if the community-based disaster preparedness systems—training, equipment, or administrative oversight—were in place, many of the lives lost on that fateful day could have been saved.

Just a month after the Swat tragedy, in another incident on the 22nd of July, 2025, in the late afternoon, a sudden and devastating flash flood, which triggered after heavy rainfall higher up in the mountains, struck the Babusar Top/Diamer Chilas road, a route used by tourists going to or coming from Gilgit Baltistan.

The ferocious flash flood came thundering down the mountain onto the Babusar road, destroying everything in its path. There were dozens of vehicles moving on the road at the time including a bus carrying a family from Punjab, returning from a trip to Skardu in Gilgit Batistan. As the torrent hit the road with massive force, it toppled the bus, sending it sliding down the mountainside. More than thirty other vehicles, including passenger coasters, were swept away by the flash floods, while ten to fifteen vehicles were completely destroyed. Three members of the same family aboard the bus were confirmed dead and dozens more injured. Seven to eight kilometres of Babusar road were completely destroyed and four connecting bridges washed away.

As panic ensued, people abandoned their vehicles; many were injured after falling on the slippery road, while many others, disoriented and in a state of shock, got lost in the wilderness as darkness descended over the mountains.

The first responders were the men from the surrounding villages, who rushed to the scene but they had no rescue equipment which could have been used to help rescue the injured, the lost or the ones that had fallen in the ravine below.

This incident, once again highlighted the critical need for community-level rescue facilities in an highly risk prone area, where a sudden flash flood or land slide can create a major disaster within a matter of minutes and the only rescue and relief can come from the local men. If some of these first responders were trained or had some basic rescue equipment, that could have made a difference between life and death for many of the victims.

Even after the initial rescue, the victims of any accident or disaster need medical care as well as emotional support as they are frightened and sometimes in shock. CBDRM can help train community members and sensitize them for post disaster care of the victims including women and children.

12 https://tribune.com.pk/story/2560675/swat-drownings-highlight-rescue-failure

Babusar top accident. The bus carrying the tourist family from Punjab and the destruction of vehicles. [13 14]

Babusar/Diamer Chilas accident July 2025

In 2025, many different locations in KPK including Swabi and Buner, experienced intense rainfall triggered landslides carrying huge boulders the size of two story buildings which crushed entire villages within minutes.[15] The total death toll by the landslides was more than 504 fatalities across KP, with 256 in Buner and 120 injuries, and 43 in Swabi.[16] In the Buner incident on 15th August 2025 massive rocks and fallen trees were swept down the mountainside in the remote Bayshonai Kalay village, after two days of intense monsoon rains, burying people and homes in their path. According to the eye witnesses, the terrifying thunder accompanying recent torrential rains was so loud that they thought that the "end of the world had come".[17]

13 https://www.arabnews.com/node/2608967/pakistan
14 https://www.geo.tv/latest/615199-rescue-efforts-underway-in-flood-hit-gb-after-three-killed-several-missing
15 https://www.ndma.gov.pk/storage/sitreps/August2025/A1EmVmPaP66uSK4kcN6f.pdf
16 https://www.dawn.com/news/1956944
17 https://www.reuters.com/business/environment/flash-floods-devastate-buner-pakistan-after-rare-cloudburst-kills-hun dreds-2025-08-17/

Bayshonai Kalay Village, Buner August 2025

The severe landslides did more than just destroy homes; it also completely wiped out the existing roads. This isolation made it impossible for the district or provincial authorities to send earth-moving equipment or rescue teams to the affected site. As a result, the affected communities were entirely cut off and isolated from any external assistance for days, meaning that very little help could reach them.

The speed and intensity of cloudburst and flash floods in mountainous terrain overwhelmed the government's disaster-response capacity as many areas in the province had become inaccessible due to landslides, washed-out roads, blocked tracks, which delayed rescue and recovery. Medicine and life saving equipment could not reach the injured for a much delayed time and they remained in grave danger even after the initial thrust of the disaster.

In disaster situations when external help cannot reach the affected area, the survival and rescue of victims depend solely on a pre-existing disaster management plan and community members who are trained and equipped for rescue and relief operations.

## Need for Participatory Approach

The preparation for the flood season by many households in KPK is generally undertaken on an individual basis, involving the procurement of provisions, bedding materials, and the identification of safe routes and shelters. However, this approach often leads to maximum losses during floods, as singular households are unable to execute all necessary preparations effectively. Only a well-coordinated participatory methodology can guarantee the synchronization of activities and the equitable distribution of responsibilities, thereby enhancing the community's readiness to mitigate disaster.

The establishment of a disaster management committee in every village susceptible to flash floods or other calamities is crucial for augmenting the capacity of households and communities to withstand the detrimental impacts of natural hazards. The formation of an organized committee unites an entire community and informs other stakeholders of available resources and protective measures against risks. The collaborative process of working toward and achieving common goals can fortify communities. It strengthens local organizations, fosters confidence, skills, and the ability to cooperate, heightens awareness, and facilitates critical evaluation.

Community involvement is essential across all phases of disaster risk management, including risk identification, prioritization, plan formulation, implementation, monitoring, and evaluation.

The community must be engaged in every dimension of the risk management process, commencing with assessment. Community-based risk assessments can be conducted utilizing Participatory Rural Appraisal (PRA) methodologies, which facilitate the collection of requisite information for evaluating the community's risk profile. A comprehensive community risk assessment allows all community members to participate, accurately identify the flood hazards they confront, and fully comprehend them. This assessment furnishes them with the necessary information to enable their active participation in the decision-making process.

Risk mapping can be a community project that encourages participation and awareness. It is an exercise that not only produces a risk map that is understood by the participants, but also informs them of potential hazards, vulnerability of risk elements. There can be roles and responsibilities assigned to different team members.

According to Pakistan Flood Situation report [18] Buner was hit by a cloudburst, a rare phenomenon where more than 100 mm (4 inches) of rain falls within an hour in a small area. In Buner, there was reportedly more than 150 mm of rain within an hour which triggered the massive land slide. But as huge amounts of timber as well as enormous boulders came rolling down in the landslide, it was evident that massive deforestation and cutting down of trees in the mountains above the village had destabilized the mountain ecosystem, transforming stable terrain into hazardous zones prone to catastrophic landslides. Also there was illegal mining going on in the area for a long time and the blasting and crushing activities by the miners had dislocated and fragmented the rocks making them extremely hazardous in case of heavy rainfall.

The massive size of boulders that rolled down from the mountains obliterated the entire village within the matter of minutes.[19] In his visit to KPK after the devastating floods the Prime Minister Shahbaz Sharif himself admitted that illegal encroachments, timber smuggling and mining was worsening the disaster.[20]

Bayshonai Kalay village Buner KPK, after the landslide August 2025

CBDRM can help raise community awareness of the dangers posed by massive deforestation, illegal mining or construction in the natural flood channels, which can increase their vulnerability and the risk of disaster, many folds during the occurrence of natural hazards including heavy rainfall. It can also give awareness of the effects of climate change on the changing weather patterns and how best to adapt to it.

18 https://www.unocha.org/publications/report/pakistan/pakistan-flood-situation-overview-6-october-2025#:~:text=15%20August:%20a%20catastrophic%20cloudburst,destruction%20and%20loss%20of%20lives.
19 https://www.instagram.com/p/DNa36dhJpS1/?img_index=13
20 https://tribune.com.pk/story/2562226/pm-shehbaz-field-marshal-munir-visit-flood-hit-k-p-assure-full-support-to-victim

Basic training for disaster risk reduction, detecting warning signs and preparedness can save lives. The voluntary teams must have basic training in using available early warning systems including advisories on official websites. They should also be able to read and understand the different terms and terminologies for hazards and know how to respond to them.

In a very well documented case in Ghizer district of Gilgit-Baltistan in August 2025, a critical early warning was given by a shepherd as he was when he spotted signs of a Glacial Lake Outburst Flood (GLOF) and promptly alerted the nearby villagers via mobile phone. This timely action reportedly enabled the safe evacuation of approximately 200 people before the floodwaters hit. The federal government later recognized the three shepherds involved, awarding them for "saving hundreds of lives."[21]

## Preparedness saves lives:

Effective Community-Based Disaster Risk Management (CBDRM) relies on distributing responsibilities across the community. It is essential to include women in preparedness training. This approach allows for the formation of multiple teams, each dedicated to managing a different facet of disaster readiness.

**Evacuation and Shelter Team:** The evacuation and shelter team which can make arrangements prior to the floods to evacuate at-risk people to safer locations if advised by the government. It can make necessary arrangements to evacuate cattle and valuables along with the people. The community would have more trust and confidence in their own committee for these sensitive tasks than any government agency.

**Search and Rescue Team:** The local trained search and rescue team for every vulnerable area, which would be prepared in case of any emergency situation and act as the first responders. The government must provide free training on basic search and rescue and also ensure the provision of necessary rescue equipment including basic search lights, binoculars, compasses, ropes, harnesses, pulleys, chain saws and pry bars to every village at risk of flash flood. Each village should have at least one or two trained dogs to provide vital assistance during search and rescue operations. In many disasters, rescue dogs have played a heroic role in saving lives. During the Feb 2023 Turkiye earthquake it was the dogs that played a central role for the search and rescue of survivors and saved hundreds of lives.

**After the devastating Turkiye earthquake 2023 trained rescue dogs saved hundreds of lives. Among them was Şilan,the German Shepherd who worked for 56 hours straight and located forty people alive, buried under the rubble.**[22]

21 https://www.geo.tv/latest/620005-gb-shepherd-hailed-as-hero-for-warning-that-saved-200-lives-in-glacier-burst
22 https://www.aa.com.tr/en/turkiye/rescue-dogs-central-to-rescue-efforts-in-quake-hit-southern-turkiye/2821129

**First aid Team:** There should also be a first aid team which can provide first aid to the injured and also mobilize and organize camps to treat the sick or injured, in case of any untowards incident during floods. It could include any doctor or health workers and midwives from the local community.

**Relief and Rehabilitation Team:** The relief and rehabilitation team can identify the needs of the community and coordinate with aid agencies to get the necessary stock of relief goods.

The National and Provincial Disaster Management Authorities can produce training manuals or small videos in local language to impart different training on search and rescue, first aid, camp management and gender based disaster management to volunteers in all villages and towns vulnerable to natural hazards throughout the year. The video training can be uploaded on different websites and also run as educational content on local cable channels.

These trained volunteers would prove to be a valuable asset as the first tier support system to district and provincial; agencies during any disaster and coordinate, plan, and implement relief delivery operations with aid agencies in an equitable manner.

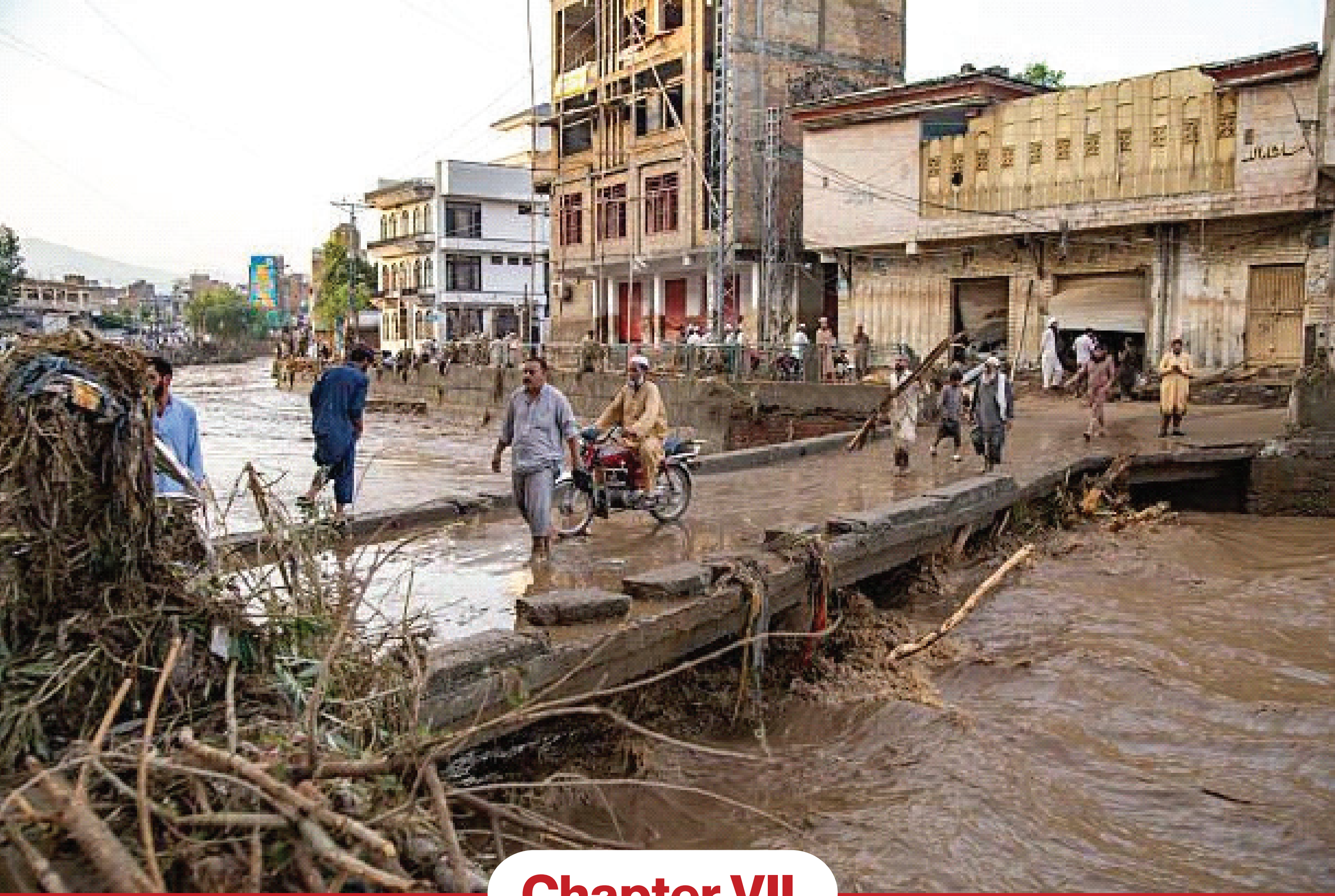
**Gender based Disaster Management:** Women are always disproportionately affected by disasters therefore addressing gender issues is crucial for effective disaster risk management. Gender-biased attitudes and stereotypes can significantly hinder and prolong the recovery process for women following a disaster. Therefore, it is essential for volunteer groups and individuals to fully grasp the gender dimensions inherent in disaster-management practices. This understanding is necessary to tackle the underlying causes of vulnerability and implement risk-reduction strategies that are both equitable and efficient.

## Need for Integrated Development

Effective disaster risk management requires a comprehensive strategy that moves beyond local-level efforts alone. While "bottom-up" approaches acknowledge and utilize the knowledge and skills of local communities, a successful system necessitates integrating these with "top-down" governmental support and responsibilities.

This integrated approach must link risk reduction actions to the broader goal of sustainable development. Establishing this connection is crucial for promoting long-term DRM strategies. Such long-term strategies must recognize the interconnected nature of disasters, poverty, and sustainable development, and understand the profound impact these factors have on all parts of civil society, particularly on groups that are already marginalized.

Pakistan's hazard patterns are rapidly intensifying due to climate change. The frequency and severity of flash floods, cloudburst events, and glacial lake breaches have increased sharply over the last decade. In the absence of formal, institutionalized CBDRM structures, communities remain highly vulnerable and often rely on improvised rescue efforts with no equipment or training. CBDRM provides a sustainable, low-cost mechanism for building resilience where state capacity is thin and terrain makes rapid response nearly impossible. By equipping communities with training, early warning tools, basic rescue equipment, and disaster awareness, CBDRM effectively bridges the gap between hazard onset and formal rescue mobilization, thereby saving lives and reducing losses.



Chapter VII

Flood Risk in Pakistan as a Compound Hydroclimate System:

# POLLUTION, MONSOON DYNAMICS AND WATERSHED PROCESSES

Dr Huma Sheikh, Ali Bin Shahid & Nawaz Haq

This chapter integrates scientific evidence across hydrology, pollution, atmospheric science and land systems. A brief summary of key findings is provided to support accessibility for non-technical readers.

### Key Takeaways

- Flood risk in Pakistan is systemic, not singular — driven by interacting climate, land and pollution processes, not rainfall alone.

  Floods mobilise pollution at scale — redistributing chemicals, plastics and contaminants across soils, water systems and ecosystems.
- Multi-pollutant contamination degrades ecosystems and productivity — combined exposures reduce water quality, agricultural output and ecosystem function, with direct implications for food security and human health.
- Atmospheric pollution alters hydroclimate dynamics — aerosols can intensify rainfall extremes, while black carbon accelerates ice melt, increasing downstream flood risk.
- Land degradation and soil saturation significantly amplify flood severity — increasing runoff and peak discharge.
- Actionable drivers lie within national control — integrated pollution control, land restoration and watershed management can directly reduce risk.
- Delaying action increases systemic risk — precautionary, integrated management is justified based on current evidence.

## 1. Introduction: Floods as Compound Hydroclimate Events

Flood disasters in Pakistan are often framed primarily as hydrological events driven by extreme rainfall. However, growing scientific evidence indicates that floods should be understood as compound hydroclimate events in which atmospheric pollution, cryosphere processes, land degradation, monsoon variability, watershed condition and hydrological dynamics interact to amplify both flood intensity and the redistribution of environmental contaminants [1–3]. In this framing, flood disasters are not simply the result of heavy rainfall over a vulnerable river basin, but the outcome of interacting atmospheric, terrestrial and hydrological systems that determine how rainfall forms, how water moves through landscapes, and what pollutants are mobilised in the process.

This system's perspective is especially important in Pakistan because the Indus River basin supports more than 200 million people, underpins one of the world's largest contiguous irrigation systems, and ultimately discharges into the Arabian Sea. Environmental processes occurring within the basin therefore influence not only inland ecosystems, agriculture and settlements, but also downstream marine environments. Flood events in Pakistan thus represent not only hydrological hazards but also large-scale environmental redistribution mechanisms, capable of mobilising contaminants stored in river sediments, urban landscapes, industrial sites, agricultural land and waste disposal zones, and transporting them through floodplains, irrigation systems and coastal waters [4–6].

This chapter synthesises peer-reviewed research and multilateral assessments to examine how flooding in Pakistan interacts with persistent chemical contamination, plastic pollution, particulate pollution, atmospheric aerosols, black carbon emissions, cryosphere destabilisation and watershed degradation. The central argument is that these interacting drivers generate compound environmental risks affecting ecosystem health, agricultural productivity, public health and long-term resilience.

Pollution is therefore not treated here as a secondary issue occurring after floods, but as part of the flood-risk system itself. Flood risk in Pakistan should therefore be understood not only as a hydrological hazard, but as the outcome of interacting atmospheric, terrestrial, ecological and pollution systems operating across the Indus basin

## 2. Floodwaters as Vectors for Persistent Chemical Pollution

Extreme floods can mobilise contaminants through several interconnected mechanisms, including sediment

sediment resuspension, wastewater overflow, infrastructure failure, and the transport of urban and agricultural runoff across floodplains. Under normal hydrological conditions, floodplains and river sediments often function as long-term storage zones for pollutants. Heavy metals, pesticide residues, PFAS, hydrocarbons and other persistent contaminants may remain adsorbed to fine sediments or bound to organic matter for prolonged periods. During high-discharge events, however, increased turbulence and shear stress can remobilise these stored pollutants and redistribute them across agricultural soils, irrigation systems and downstream river corridors [5,6].

This process is critical because it transforms flood disasters from purely hydrological events into contamination redistribution events. Floodplains that receive repeated sediment deposition may function as both sinks and secondary sources of pollutants. During subsequent floods, previously stored contaminants may be reactivated and transported again, creating cumulative contamination pathways.

Pakistan-specific evidence confirms the presence of persistent chemical contamination within parts of the Indus-connected environment. PFAS have been detected in 37%–100% of freshwater reservoir samples in Punjab, with summed PFAS concentrations reaching 114.1 ng/L at Head Panjnad, exceeding the EU 100 ng/L drinking-water guideline. Ecological risk assessment identified PFBS as high risk to green algae and PFOA as high risk across multiple aquatic organisms. PFAS have also been detected in edible fish from the Indus basin at concentrations up to 45.4 ng/g wet weight, with long-chain PFAS such as PFOA, PFOS, PFHpS and PFDS dominating the burden, indicating aquatic persistence and bioaccumulation, with implications for dietary exposure [7–9]. Flood events therefore do not introduce entirely new pollutant classes; rather, they enlarge the spatial footprint and exposure pathways of contaminants already present in aquatic systems.

Pesticide contamination provides another important pathway. Following the 2010 floods in Charsadda, pesticide residues including o,p -DDT and pyridaben were detected in drinking-water samples at concentrations exceeding recommended safety thresholds, indicating direct post-flood contamination of domestic water sources [10]. More recent work in the Indus system reported pesticide concentrations reaching approximately 0.83 µg/L in water, 12.37 µg/g dry weight in sediment, and 14.27 µg/g wet weight in fish tissue, with compounds such as endosulfan and cypermethrin exceeding environmental safety limits and endosulfan and triazophos producing target hazard quotient values above 1, indicating meaningful human-health risk [11]. In the Chenab River, organochlorine pesticides including heptachlor, α-HCH and dieldrin were reported at 0.54–122 ng/L, with significant carcinogenic and ecological risk identified [12]. Additional Lahore-related work found pesticide concentrations exceeding toxicity thresholds for earthworms, crustaceans and algae, indicating potential disruption of soil fertility and aquatic food webs [13].

Endocrine-disrupting chemicals represent another important emerging concern. Wastewater and surface-water studies in Lahore reported 16 endocrine-disrupting chemicals and transformation products, with 100% detection frequency for many compounds in wastewater, concentrations reaching 1310 ng/L for estriol, and median surface-water concentrations of 54.6 ng/L for bisphenol-A (BPA) [14]. Risk assessment indicated high ecological risk and significant estrogenic activity, reinforcing concern that these compounds can affect reproduction and development in aquatic organisms at very low concentrations and as complex mixtures [14].

Heavy metal contamination also remains a major concern. Flood-driven mobilisation of contaminated sediments can redistribute lead, cadmium, chromium, nickel and other metals across agricultural soils, irrigation systems and wetlands. Evidence following the 2022 superflood showed groundwater contamination in Charsadda and Nowshehra with chromium, nickel and lead above WHO and USEPA drinking-water limits, while sediments and agricultural soils were contaminated especially by cadmium, lead and nickel, with cadmium classified as extreme contamination in geo-accumulation analysis [15]. Additional work in the Adenzai floodplain identified potentially harmful elements in groundwater, including chromium, cadmium and lead, at levels of concern relative to WHO thresholds, indicating risks for drinking, domestic use and agriculture [16]. A broader Lahore study of metal pollution also shows that substantial metal burdens are already present in regional water systems, with approximately 26% of groundwater samples unsuitable for drinking and carrying cancer risk. Regarding ecological risks, almost all the water samples exceeded the chronic and acute threshold limits for algae, fish, and crustaceans. Only 42% of groundwater samples were below the acute threshold limits. In the case of pollution index, 72%, 56%, and 100% of samples collected from canals, river Ravi, and drains were highly contaminated. [17].

Floodwaters can also mobilise wastewater contamination by overwhelming sanitation and drainage systems and exposing weaknesses in wastewater management, monitoring and treatment, thereby increasing the risk that sewage and other wastewater-associated contaminants enter domestic and agricultural water sources [6,18]. In this way, flood disasters can create multi-exposure chemical events rather than isolated contaminant incidents, reinforcing the need to treat them as contamination emergencies as well as hydrological disasters.

## 3. Microplastics, Flood Pulses and River Transport

Plastic pollution in river systems is increasingly understood as episodic and event-driven, rather than continuously exported at a steady rate. High-discharge floods can mobilise plastics stored in sediments, on riverbanks and within floodplain deposits, meaning short-lived events may dominate annual plastic export from river basins [4].

This is particularly relevant in Pakistan, where seasonal discharge variability is high and flood pulses can be intense. Pakistan-specific studies identify substantial microplastic burdens in the River Ravi, the Soan River, and in freshwater systems connected to the wider Indus basin [19–21]. Sediment analyses from Himalayan river systems including the Indus have reported microplastic concentrations ranging from approximately 525 to 1 752 particles per kilogram of sediment, indicating that riverbed environments act as significant storage zones for plastic particles [22]. Studies from the Soan River have detected 132.7–641.3 particles per cubic metre in surface waters, and more recent field assessments have recorded 318–500 particles per 0.25 $m^2$ in river sediments, confirming active transport and accumulation in tributary systems [20,21].

The significance of these findings is that plastics are already embedded within freshwater ecosystems, not simply present as visible litter. Once plastics enter rivers they may be transported, trapped temporarily in sediments or riparian vegetation, and later remobilised during high-flow events. This means flood pulses can act as plastic flushing events, transferring material from terrestrial and riverine storage zones into downstream ecosystems.

At basin scale, the Indus also functions as a major conduit linking inland plastic waste to the marine environment. Basin-scale modelling suggests that approximately 10,000 tonnes of plastic waste enter the Arabian Sea each year via the Indus system [23]. More broadly global river-plastic assessments show that a relatively small number of river systems account for a disproportionate share of plastic transport to the sea [24]. This establishes a clear river-to-ocean pathway, linking inland waste generation to downstream marine contamination.

Plastic contamination has also been documented in aquatic biota. Microplastic particles have been detected in freshwater fish from Panjnad Barrage and in the endangered Indus River dolphin, demonstrating biological exposure within the river system [25,26]. These findings are important because they show that plastic pollution is already entering freshwater food webs in Pakistan.

## 4. Interaction Between Microplastics and Chemical Pollutants in Flood-Affected Environments

The interaction between microplastics and chemical pollutants is a critical but often underappreciated dimension of flood-related contamination. Microplastics are not only persistent physical pollutants; they can also act as sorption surfaces and mobile carriers for a wide range of chemical contaminants. Their importance derives from their hydrophobic polymer structure, high surface-area-to-volume ratio, and the fact that environmental weathering can increase available binding sites. UV-driven aging, surface oxidation and biofilm formation can enhance the adsorption behaviour of plastic particles in surrounding water and sediments [30,31].

Microplastics can adsorb a wide range of chemical contaminants, including persistent organic pollutants, pesticides, pharmaceuticals, endocrine-disrupting chemicals and heavy metals. Experimental and field evidence shows that compounds such as PCBs and PAHs can accumulate on plastic surfaces, and that pesticide and pharmaceutical residues can also sorb to microplastic particles [30–32]. This means plastics can function as mobile pollutant reservoirs, moving not only as debris but also as carriers of chemically enriched burdens through rivers, stormwater systems and floodplains.

This mechanism becomes especially important during floods. High-discharge floodwaters can mobilise plastic particles from sediments, riverbanks, road runoff, waste sites and floodplain deposits at the same time that they remobilise sediment-bound metals, pesticide residues, wastewater-associated contaminants and industrial chemicals [4–6,30,31]. Floods can therefore create compound pollution pathways, in which plastics and chemicals are redistributed together rather than as separate systems. Once redeposited in floodplain soils, agricultural fields or aquatic habitats, these particles and their associated contaminant burdens may persist and remain available for later uptake or release [4–6,30,31].

The toxicological significance of this interaction is not merely theoretical. Experimental and review evidence indicates that microplastics can modify the environmental behaviour and biological effects of co-occurring contaminants, including PFAS, pesticides, pharmaceuticals and heavy metals, with reported effects on oxidative stress, phytotoxicity, metal uptake and microbial activity [30,31]. A growing global literature provides more specific examples of these combined-exposure interactions across aquatic and terrestrial systems; the central point here is that pollutant mixtures may amplify mobility, persistence and biological exposure more than single pollutants considered in isolation [30,31].

For Pakistan's floodplains, the implication is significant. Floodwaters can deposit microplastics, together with adsorbed or associated contaminants, onto cropland, irrigation channels and wetland environments [4–6,30,31]. Once present in these systems, some associated contaminants may desorb under changing pH, salinity or biological conditions, or become available through ingestion by aquatic organisms and soil fauna [30,31]. Microplastics should therefore be understood not only as pollutants in their own right, but also as dynamic vectors that can amplify chemical mobility, persistence and biological exposure during and after major flood events [4–6,30,31].

## 5. Agriculture, Food Security and Human Exposure

Floodplain agriculture creates direct pathways through which contaminated sediments can enter food production systems. During flood events, sediments deposited on cropland soils may contain mixtures of plastic particles, heavy metals, PFAS, pesticide residues and microbial contaminants.

Microplastics and associated chemicals may therefore move through pathways linking soil, crops, livestock and human consumption. Global assessments confirm the presence of micro- and nanoplastics across environmental media and food systems, highlighting potential environmental-health risks following major flood events [27,28,33]. The issue is not only one of environmental contamination but of exposure transfer into productive systems.

From an agricultural perspective, flood-driven contamination can affect productivity through several mechanisms. Heavy metals and persistent chemical contaminants may interfere with plant growth, root physiology and microbial processes in soils. Microplastics may alter soil physical structure, infiltration behaviour, rhizosphere conditions and microbial interactions [27–29]. Soil contamination can therefore affect both yield stability and soil fertility.

Pakistan's irrigation system adds another layer of vulnerability. Water and sediments redistributed during floods can enter canals and irrigation infrastructure, extending contaminant pathways beyond the immediate flood zone. This is particularly important because Pakistan's agricultural economy is deeply dependent on irrigated production, meaning contamination of water and soils can have system-wide implications for food security, livelihoods and rural incomes.

Flood disasters also amplify health risks through the simultaneous mobilisation of chemical pollutants and pathogenic microorganisms. Disruption of sanitation systems and water supply infrastructure increases the likelihood of compound environmental-health pressures after major flood events [18,42–45]. Communities may therefore be exposed not only to contaminated floodwaters, but also to polluted drinking water, contaminated food and dust from drying sediments. A recent synthesis published in The Lancet Planetary Health emphasises that micro- and nanoplastics are now detected across environmental media including food systems, drinking water and airborne dust, and identifies biologically plausible pathways of harm including oxidative stress, inflammatory responses and cellular disruption [33]. This substantially strengthens the relevance of pollution redistribution to flood-risk governance.

## 6. Human Health Implications

Human exposure to flood-mobilised pollution may occur through ingestion, inhalation, dermal contact and food-chain transfer. These pathways are particularly important because flood events do not simply increase pollutant loads in water; they increase the probability that pollutants move across environmental compartments into human exposure routes.

Microplastics are now recognised as pervasive environmental pollutants capable of entering the human body. Evidence has expanded rapidly in recent years. Microplastics have been detected in human blood, indicating systemic exposure [34]. They have also been reported in human semen, with findings suggesting possible associations with reduced semen quality [35]. Additional studies and recent reviews have identified microplastics in human ovarian follicular fluid, semen and testicular tissue, raising concerns regarding reproductive health and fertility [33,36–39].

These findings are important because they indicate not merely environmental contamination but biological penetration into human reproductive environments. The concern is not only the physical presence of particles. Micro- and nanoplastics may also carry adsorbed pollutants or release additives, while toxicological evidence points to mechanisms including oxidative stress, inflammatory signalling, endocrine disruption, mitochondrial dysfunction and cellular injury [33,36–39]. These are biologically plausible pathways for reproductive, developmental and systemic health effects.

Chemical contaminants associated with floods present additional risks. PFAS have been associated with immune and endocrine effects. Heavy metals such as lead, cadmium and chromium are linked to neurological, cardiovascular and developmental harm. Many pesticide compounds are associated with endocrine, reproductive or neurotoxic effects. Flood mobilisation expands the environmental distribution of these pollutants and therefore the scale of potential human exposure [7–17].

Importantly, exposure after flood events is rarely to one pollutant in isolation. Human populations may be exposed to mixed burdens of plastics, metals, pesticides, wastewater residues and pathogens, and mixture effects may differ from single-compound toxicity. This complicates risk assessment and underscores the need for precautionary management. Flood-related displacement can further amplify these risks by concentrating affected populations in overcrowded and under-served settings with inadequate access to safe drinking water, sanitation, and healthcare. In such environments, exposure is shaped not only by contaminated floodwaters, but also by sewage contamination, stored or untreated water, locally sourced food, and damaged health and sanitation infrastructure. These combined pressures increase the risk of water-borne disease and other communicable illnesses, while also intensifying exposure to chemical, particulate, and wider pollution-related burdens. They can be especially severe for children, pregnant women, and other vulnerable groups, reinforcing the need to treat floods as complex environmental health emergencies rather than solely hydrological events [42–46].

While this chapter focuses on environmental exposure pathways relevant to flood risk, the wider scientific literature demonstrates that pollution exposures—including microplastics and nanoplastics, chemical contaminants and particulate matter—are associated with a broader range of health outcomes, including respiratory and cardiovascular disease, endocrine disruption, neurological and carcinogenic effects [33,42–46].

Flood events may amplify these risks by increasing exposure intensity, mobility, and cross-media transfer (water, soil, air, and food systems). However, a comprehensive assessment of these health outcomes lies beyond the scope of this chapter, which focuses on their role as systemic risk amplifiers within flood dynamics.

## 7. Amplified Environmental Risks from Combined Pollutants

Environmental contamination during flood events rarely involves a single pollutant acting alone. Floodwaters typically redistribute mixed contaminant systems in which plastics, PFAS, pesticide residues, heavy metals, endocrine disruptors, wastewater contaminants and particulate matter interact physically and chemically across environmental compartments. The environmental significance of these mixtures lies in the fact that they may alter bioavailability, persistence, mobility and toxicity relative to single contaminants considered in isolation.

Microplastics are especially important in this context because they can act as transport vectors for chemically enriched burdens. Their hydrophobic surfaces and high surface-area-to-volume ratios facilitate adsorption of hydrophobic organic compounds, pesticides, pharmaceuticals, endocrine-disrupting chemicals and metals from surrounding water and sediments. Weathered plastics may be even more reactive because UV degradation, surface oxidation and biofilm formation create additional binding sites. As a result, floodwaters do not simply move plastics and chemicals separately; they move chemical-enriched plastics as part of one contaminant system.

This matters ecologically because contaminant mixtures can produce outcomes that differ from those of individual pollutants alone. Review evidence indicates that interactions between microplastics and co-occurring contaminants can modify oxidative stress responses, phytotoxicity, metal uptake and microbial activity, with implications for soil function, plant health, aquatic toxicity and food-chain exposure [30,31]. These findings suggest that combined pollutant systems may influence environmental behaviour and biological effects more severely than single pollutants considered independently.

For flood-prone regions such as Pakistan, the policy implication is that floods should not be treated simply as hydrological events that happen to encounter pollution. They should be recognised as compound contamination events, capable of redistributing mixtures of pollutants across agricultural soils, water systems and ecological habitats at scales far larger than the original contamination sources.

## 8. Particulate Pollution Pathways: Tyre Wear, Brake Dust and Stormwater Transport

In addition to plastics and dissolved or sediment-bound chemicals, particulate pollution from non-exhaust vehicle emissions is an increasingly important environmental pathway. Tyre wear particles, brake wear particles and road surface fragments accumulate on urban surfaces and are mobilised by rainfall and runoff.

Tyre wear is now recognised as one of the largest sources of microplastic pollution globally, with estimated releases of 0.23 to 4.7 kg per person per year depending on traffic intensity and local conditions [40]. These particles are composed of synthetic elastomers, carbon black, zinc compounds and a range of additives, making them relevant not only as plastic particles but as chemical carriers.

Urban runoff studies show that tyre-derived particles and other anthropogenic microparticles can account for a substantial share of particulate loads in stormwater systems and receiving waters [41,47–49]. This is significant because it links everyday urban traffic directly to riverine and floodplain particulate contamination.

Brake wear particles represent another major source of particulate contamination. These particles are typically metal-rich, containing iron, copper, zinc and other compounds produced through friction [50,51]. Laboratory evidence indicates that brake wear nanoparticles can cross epithelial barriers in small amounts and alter airway protective or repair functions, reinforcing their environmental and health relevance [50].

Stormwater systems therefore act as critical transport pathways linking air pollution, road-derived particulates and aquatic contamination [41,47–49,51]. During flood events, these processes intensify as larger runoff volumes mobilise accumulated pollutant loads from roads, parking areas, construction sites and industrial surfaces.

## 9. Crop Burning and Atmospheric Pollution

Agricultural residue burning is a major source of particulate pollution in South Asia and should be treated as part of the broader flood-risk system. Crop burning releases large quantities of $PM_{2.5}$, $PM_{10}$, black carbon, organic carbon and trace metals into the atmosphere, contributing to regional haze and atmospheric loading [52–55].

These particles can travel significant distances before being deposited onto soils, crops, water bodies and glacier surfaces. Once deposited on land, some may later be remobilised by rainfall and floodwaters, creating an additional link between air pollution, land contamination and water pollution [56–58].

Crop burning is therefore relevant in two distinct ways. First, it contributes to particulate deposition that may later enter runoff systems. Second, it is an important regional source of black carbon and aerosol loading, linking directly to cloud microphysics, rainfall formation and cryosphere destabilisation [52–58].

## 10. Aerosols, Cloud Microphysics and Rainfall Intensity

Atmospheric aerosols influence rainfall formation through their role as cloud condensation nuclei (CCN). In cleaner atmospheric conditions, cloud droplets form on a smaller number of nuclei and exhibit broader size distributions, allowing larger droplets to develop and coalesce efficiently. In more polluted conditions, many small droplets form on abundant fine aerosol particles, narrowing the droplet spectrum and delaying precipitation onset [52,53].

The result is that atmospheric moisture can accumulate within clouds until rainfall eventually occurs as short-duration, high-intensity downpours. This mechanism is important because it provides a physically plausible way in which pollution may influence the character of rainfall, not merely air quality.

The aerosol note underlying this chapter adds important quantitative detail. In polluted atmospheric environments, CCN concentrations may rise into the range of roughly 1,000–5,000 particles $cm^{-3}$, narrowing the droplet-size spectrum sufficiently to suppress efficient collision–coalescence. Under such conditions, the altitude at which precipitation begins can shift from around 1–1.5 km above cloud base to more than 5 km, allowing clouds to store much larger water loads before release. When precipitation finally begins, it may occur as concentrated cloudburst-type events rather than distributed rainfall.

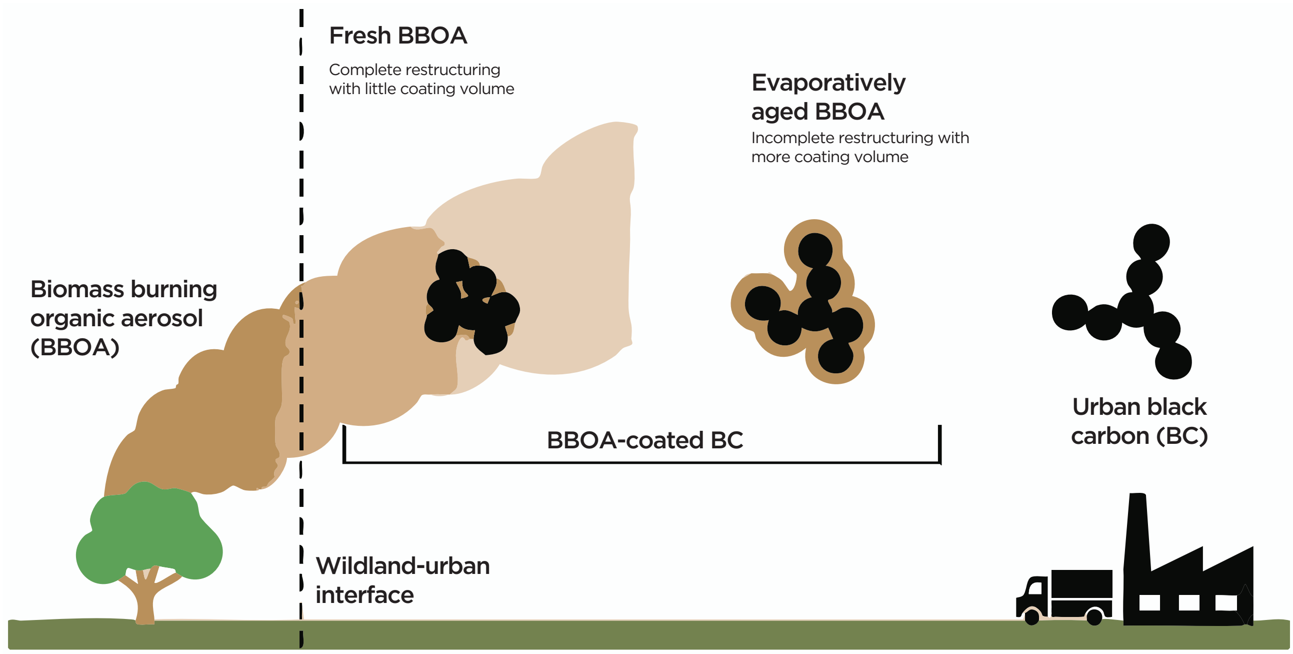
A further useful metric is relative dispersion of droplet sizes. Where broad droplet spectra are maintained, rainfall formation remains efficient; where the distribution narrows, rainfall is delayed. The aerosol note indicates that giant biological CCN can restore relative dispersion above 0.3, whereas heavily polluted fine-mode conditions may suppress it below 0.2, drastically reducing rain efficiency until sufficient growth occurs aloft.

The broader implication is critical: the same broad atmospheric moisture load that would arrive over an intact, biologically functioning catchment as sustained moderate rain can instead be released over degraded and aerosol-loaded land as a concentrated cloudburst within hours. Pollution therefore changes not just atmospheric composition but rainfall release dynamics.

Observational and modelling studies suggest that anthropogenic aerosols influence rainfall intensity and monsoon variability across South Asia through both radiative and microphysical pathways [53-55]. The importance of this lies in the connection between aerosol loading and the increased likelihood of intense precipitation bursts associated with flash floods and localised flood extremes.

## 11. Black Carbon, Cryosphere Destabilisation and Hydroclimate Volatility

Black carbon affects flood risk through both atmospheric and cryospheric pathways. When deposited on snow and glacier surfaces, black carbon reduces albedo, increasing solar absorption and accelerating melt [56,57]. This mechanism is especially relevant to the Himalayan–Karakoram–Hindu Kush region, which supplies meltwater to the Indus system. Accelerated melt can alter seasonal runoff timing, contribute to glacial lake expansion and increase the risk of glacial lake outburst floods (GLOFs). Measurements of black carbon in seasonal snowpack near K2 and the Godwin-Austen glacier provide Pakistan-proximate evidence that deposition-driven melt processes are relevant to the country's hydrology [58].
Black carbon therefore contributes not only to long-term glacier retreat but also to hydroclimate volatility, linking atmospheric pollution to downstream flood hazard.




## 12. Land Degradation, Soil Moisture and Flood Hydrology

Land-surface conditions strongly influence how rainfall translates into runoff and flood discharge. Vegetated landscapes promote infiltration and moderate runoff, whereas degraded, compacted or urbanised surfaces increase runoff fractions and peak discharge [59].

Antecedent soil moisture is a crucial determinant of flood magnitude. Recent hydrological work demonstrates that pre-existing soil saturation can significantly amplify peak discharge even where rainfall intensity is not exceptional [60]. This means that moderate or prolonged rainfall over already saturated catchments may produce larger floods than more intense storms over drier soils.

Recent analysis of CCN dynamics and flood hydrology provides an important quantitative dimension [62]. It indicates that the divergence between atmospheric-event intensity and realised flood response is strongly controlled by antecedent soil moisture, and that including soil-moisture state in hazard assessment can improve correct flood classification by more than 30%. This is a major point because it links atmospheric storm behaviour directly to catchment response.

Land degradation therefore amplifies flood severity independently of rainfall totals. Deforestation, compaction, erosion and the loss of infiltration capacity alter both watershed hydrology and, through energy partitioning, land–atmosphere interactions. At the same time, ecologically intact landscapes may provide atmospheric buffering through biological aerosol particles and giant CCN, which may support more efficient precipitation formation under some conditions [62].

## 13. Land–Atmosphere Feedbacks, CAPE and Forest Buffering

Expert synthesis of land-atmosphere feedbacks and biological CCN further strengthens this argument [62]. Forested landscapes direct a larger share of incoming radiation into latent heat through evapotranspiration, while degraded or bare landscapes convert more energy into sensible heat, increasing near-surface temperature and atmospheric instability. In practical terms, this raises Convective Available Potential Energy (CAPE) and can intensify convective storm potential.

This analysis indicates that forested catchments may exhibit CAPE values of roughly 0.8–1.5 kJ $kg^{-1}$, while degraded surfaces may increase CAPE to 2.0–3.5 kJ $kg^{-1}$. It also contrasts about 10% runoff in forested catchments with approximately 55% runoff in urbanised or heavily degraded catchments. These figures are highly relevant because they show that atmospheric and hydrological amplification can reinforce one another: degraded surfaces make storms stronger and catchments less able to absorb them.

A particularly important concept from the note is the role of biological giant CCN. Mature forest continuously supplies large biological particles — fungal spores, pollen fragments and other biogenic aerosols — that can function as giant CCN. Even a 1–5% giant CCN fraction may be enough to restore broader droplet dispersion and trigger earlier rainfall onset even under polluted fine-mode conditions. As the note puts it, the forest does not remove the pollution; it restores the rain [63,64]. This means deforestation removes both a hydrological buffer and an atmospheric one.

## 14. Orographic Effects and Ridge Bypass

Pakistan's topography adds another layer of sensitivity. Lower barriers such as the Salt Range, Margalla Hills and Galyat normally help distribute precipitation across multiple ridges. But when aerosol loading and surface heating raise cloud base and suppress early rainfall, these lower ridges may be bypassed and a larger moisture burden discharged higher and more abruptly. This can concentrate rainfall into narrower zones and contribute to more extreme local flood outcomes.

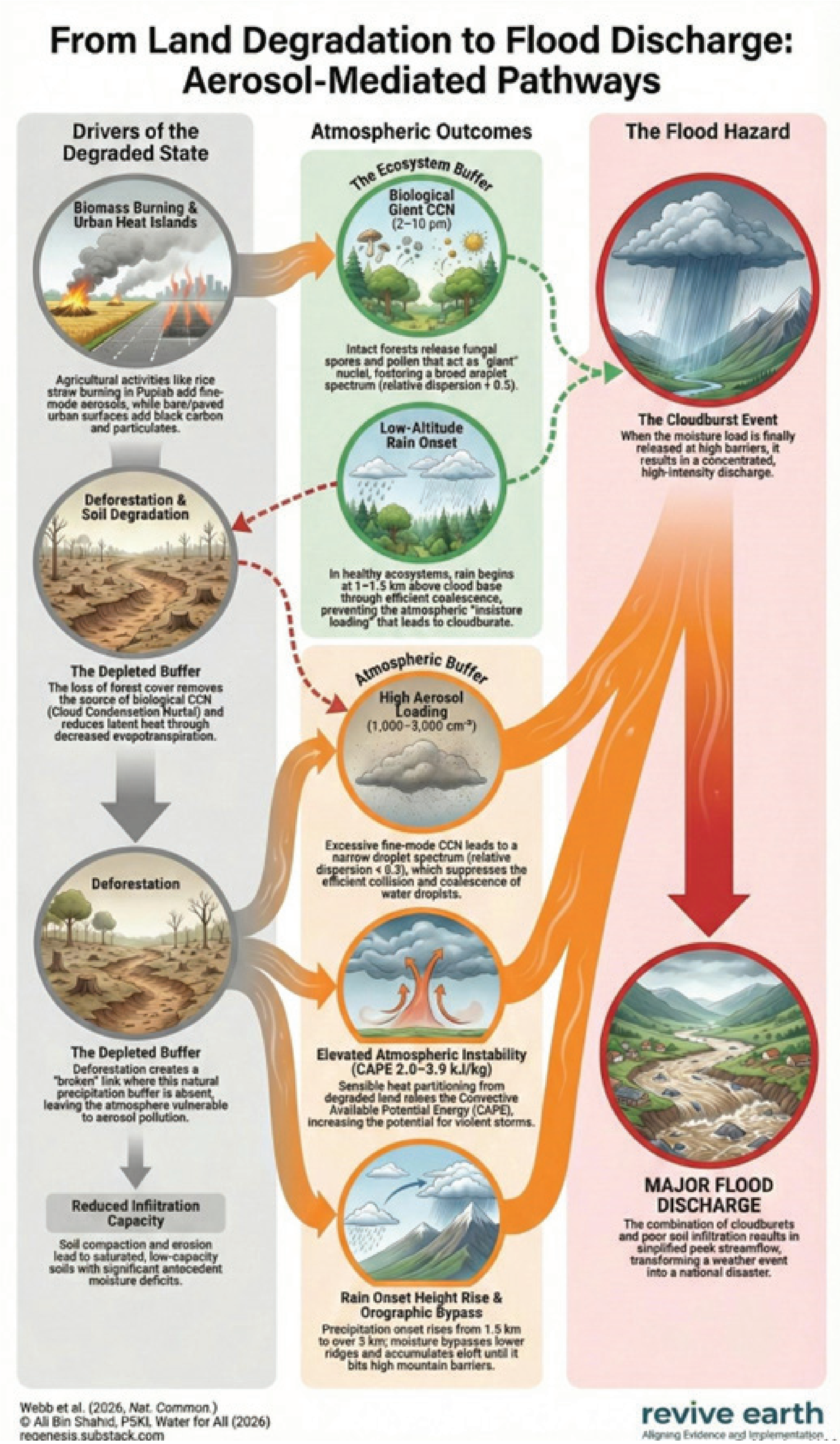
The aerosol note further highlights the interaction with Western Disturbances, whose cold upper core can pass through while lower moisture is stripped, creating steep lapse-rate structure and unstable conditions. In that setting, orographic barriers can act as local triggers for abrupt precipitation release. This mechanism helps explain how monsoon rainfall in Pakistan may become more spatially concentrated under conditions of aerosol loading, land degradation and altered atmospheric instability.

## 15. Monsoon Variability and Extreme Rainfall

Pakistan's major flood events reflect interactions among monsoon circulation anomalies, moisture transport, antecedent soil saturation, orographic uplift and cryospheric contributions. Analysis of the 2022 Pakistan floods identified multi-day extreme rainfall over saturated basins as a key driver and linked the event to large-scale atmospheric circulation anomalies [3,65].

These findings align with the IPCC Sixth Assessment Report, which concludes with high confidence that heavy precipitation events have intensified across most land regions, including South Asia, due to anthropogenic warming [1]. Observational synthesis by the World Meteorological Organization similarly indicates that the hydrological cycle is intensifying, with increasing atmospheric water vapour and heightened precipitation extremes [2].

This section is critical because it ensures the chapter remains grounded in Pakistan's actual flood climatology. Pollution and land degradation are not presented as sole causes, but as risk amplifiers within a monsoon-driven hydroclimate system.



From Land Degradation to Flood Discharge: Aerosol-Mediated Pathways
Drivers of the Degraded State
Atmospheric Outcomes
The Flood Hazard
Biomass Burning & Urban Heat Islands
Agricultural activities like rice straw burning in Pupiab add fine-mode aerosols, while bare/paved urban surfaces add black carbon and particulates.
The Ecosystem Buffer
Biological Giant CCN (2–10 pm)
Intact forests release fungal spores and pollen that act as "giant" nuclei, fostoring a broed araplet spectrum (relative dispersion + 0.5).
Low-Altitude Rain Onset
In healthy acosystems, rain begins at 1–1.5 km above clood base through efficient coalescence, preventing the atmospheric "insistore loading" that leads to cloudburate.
The Cloudburst Event
When the moisture load is finally released at high barriers, it results in a concentrated, high-intensity discharge.
Deforestation & Soil Degradation
The Depleted Buffer
The loss of forest cover removes the source of biological CCN (Cloud Condensetion Nurtal) and reduces latent heat through decreased evopotranspiration.
Atmospheric Buffer
High Aerosol Loading (1,000–3,000 cm⁻³)
Excessive fine-mode CCN leads to a narrow droplet spectrum (relative dispersion < 0.3), which suppresses the efficient collision and coalescence of water dropists.
Deforestation
The Depleted Buffer
Deforestation creates a "broken" link where this natural precipitation buffer is absent, leaving the atmosphere vulnerable to aerosol pollution.
Elevated Atmospheric Instability (CAPE 2.0–3.9 kJ/kg)
Sensible heat partitioning from degraded land raises the Convective Available Potential Energy (CAPE), increasing the potential for violent storms.
Reduced Infiltration Capacity
Soil compaction and erosion lead to saturated, low-capacity soils with significant antecedent moisture deficits.
Rain Onset Height Rise & Orographic Bypass
Precipitation onset rises from 1.5 km to over 3 km; moisture bypasses lower ridges and accumulates eloft until it bits high mountain barriers.
MAJOR FLOOD DISCHARGE
The combination of cloudburets and poor soil infiltration reaults in simplified peek streamflow, transforming a weather event into a national disaster.
Webb et al. (2026, Nat. Common.)
© Ali Bin Shahid, PSKI, Water for All (2026)
regenesis.substack.com
revive earth
Aligning Evidence and Implementation

## 16. Emerging Science, the Sea Surface Microlayer, and Model Gaps

Recent research highlights that several ocean–atmosphere exchange processes remain incompletely characterised in climate-risk assessment. The sea surface microlayer (SML), the thin physicochemical boundary at the ocean surface, has distinct biological and chemical properties and plays an important role in air–sea gas exchange, marine aerosol formation and cloud-related processes [66,67,73]. Its importance is therefore not limited to marine ecology; it is also relevant to atmospheric chemistry, hydrological cycling and climate-risk assessment. [66,67,73].

The scientific significance of the SML is not new. A GESAMP assessment produced under the UN system highlighted the SML's role in global change in 1995, following previous related work, and recorded concern that its significance may have been underestimated, both as a site of adverse biological effects and as a medium for the transfer of energy and material between sea and atmosphere [70]. This is important because it shows that the issue was recognised at expert multilateral level decades ago, even though it has not been incorporated into mainstream hydroclimate-risk narratives to the same degree as greenhouse-gas and aerosol discussions. [70]

Mainstream peer-reviewed work now reinforces that the SML should be treated as a globally important interface rather than a trivial surface film. Perspective and review papers describe the SML as a climate-relevant boundary over much of the Earth's surface, with physicochemical and biological properties distinct from underlying waters and with implications for gas exchange, particle transfer and aerosol generation [66,67,73]. Recent multidisciplinary work further identifies the SML as a biogeochemical hotspot whose properties are strongly linked to biological communities and which can materially influence heat and gas exchange. Importantly, recent authors argue that incorporating SML dynamics into Earth-system models would improve climate prediction and ocean–atmosphere interaction studies [67,71]. [66,67,71,73]

The pollution dimension strengthens the warning further. Reviews show that the SML can become enriched in pollutants relative to underlying waters, including hydrophobic organic contaminants, petroleum hydrocarbons, PAHs, chlorinated compounds, organotins and metals [72]. This makes the SML not only a regulatory interface but also a potentially sensitive concentration zone for pollutant loading. Emerging work has additionally raised concern that pollution of the SML by microplastics, hydrophobic chemicals and black carbon may disrupt its normal functions and alter evaporation, aerosol production and rainfall-related processes [67,69,72]. While these pollution-driven hydroclimate effects remain an emerging field, the direction of concern is scientifically credible and potentially highly significant. [67,69,72]

Additional recent evidence also suggests that polluted surface waters can contribute to atmospheric contamination pathways more directly than is often assumed. New work has identified wastewater-derived chemicals in coastal aerosols, pointing to an under-recognised water-to-air transfer route from contaminated waters into the atmosphere [74]. Pakistan's own coastal waters are also subject to substantial domestic and industrial effluent pollution, making the concern locally relevant [76]. Other recent studies have found metal-bearing anthropogenic microparticles floating within the SML itself, indicating that mixed pollutant burdens can co-occur directly within this surface boundary [75]. Taken together, these findings strengthen the case that the SML is not a marginal curiosity but an important interface through which pollution, atmospheric chemistry and hydrological processes may interact. [74,75]

For a country such as Pakistan, this issue deserves particular attention. Pakistan is already highly vulnerable to disruptions in the water cycle, including monsoon variability, extreme rainfall, cryosphere-related runoff shifts and compound flood risks [1–3,65]. In that context, any process capable of influencing evaporation, aerosol formation, cloud microphysics or rainfall release dynamics has potentially large relevance. The policy significance of this section is therefore not that SML science overturns established flood mechanisms, but that it identifies a credible and potentially high-impact area of scientific uncertainty that has not received proportionate policy attention. [1–3,65–67,69–75]

A precautionary approach is therefore justified. Given the potential implications for humidity, cloud formation, rainfall intensity and broader hydroclimate stability, urgent targeted research is warranted to determine the magnitude of these effects more firmly, improve model representation, and clarify the extent to which pollution-driven SML disruption may amplify extreme weather risks [67,69–71,73–75]. At the same time, reducing pollutant loads that can affect the SML — including plastics, hydrophobic chemical contaminants, black carbon and poorly treated wastewater discharges — is a prudent action pathway in its own right. For Pakistan, there is a strong case not only to support further investigation, but also to lead by example in promoting reduction of pollution pressures on the air–sea interface as part of wider climate, water and flood-risk governance. [67,69–75].

## 17. Compound Hydroclimate Risk Framework

Flood disasters in Pakistan arise from the interaction of multiple environmental drivers operating across atmospheric, terrestrial and hydrological systems. Four interacting mechanisms are particularly relevant:

**Atmospheric pollution and aerosol loading** — combustion aerosols and biomass-burning emissions can alter cloud microphysics and influence rainfall intensity by modifying CCN populations [52-55].

**Cryosphere destabilisation through black carbon deposition** — black carbon on snow and glacier surfaces reduces albedo and accelerates melt across the Himalayan–Karakoram–Hindu Kush region [56-58].

**Land degradation and catchment hydrology** — deforestation, soil degradation and urbanisation can increase runoff fractions and peak discharge by reducing infiltration capacity and altering land–atmosphere energy exchange [59,60,62-64].

**Pollution mobilisation during flood events** — floodwaters redistribute persistent pollutants including PFAS, pesticides, heavy metals and plastic debris across floodplains and agricultural soils, transporting contaminants downstream through river systems [4–29].

Together these processes form a compound hydroclimate risk system, in which atmospheric dynamics, land management and pollution sources interact to amplify both flood intensity and environmental exposure pathways.

## 18. Evidence and Uncertainty

Extreme floods arise from the interaction of multiple drivers rather than a single causal factor. Atmospheric circulation patterns, monsoon variability, soil moisture conditions, land-use change, aerosol loading and cryosphere dynamics all influence rainfall intensity and hydrological response [1–3,52–60,65].

Pollution and land degradation should therefore be understood as risk amplifiers within a broader climate and hydrological system, rather than as isolated causes of flooding. This framing preserves causal nuance while still recognising that land management and pollution control are directly relevant to flood risk [4–29,52–60,65].

While uncertainties remain in quantifying the precise contribution of individual drivers such as aerosol loading, pollutant interactions and emerging ocean–atmosphere processes, the convergence of evidence across multiple scientific domains indicates that these factors can influence hydroclimate behaviour and environmental exposure pathways. In complex environmental systems, waiting for full quantification of each mechanism before taking action may delay effective risk reduction. A precautionary approach, grounded in established scientific principles and supported by converging lines of evidence, supports the integration of pollution control, land management and atmospheric considerations into flood-risk governance [1–3,52–60,65–75].

## 19. Source-to-Sea Pollution Pathways

Floodwaters mobilise contaminants stored in urban landscapes, agricultural soils, river sediments and waste sites and transport them through river systems into coastal waters. Because Pakistan's major rivers ultimately discharge into the Arabian Sea, upstream pollution management influences downstream marine ecosystems.

This perspective aligns with source-to-sea environmental management frameworks, which recognise the connectivity between terrestrial pollution sources, freshwater systems, coastal zones and ocean environments [68]. Managing land-based pollution sources therefore contributes not only to domestic environmental protection, but also to reducing pollutant loads entering marine ecosystems.

This source-to-sea perspective also reinforces the wider argument of this chapter: pollutants mobilised upstream do not remain confined to the places where they originate. Tyre- and brake-derived particulates, wastewater-associated contaminants, persistent chemicals, plastics and sediment-bound pollutants can be mobilised by runoff and floods, transported through rivers and estuaries, and ultimately contribute to coastal and marine pollution burdens [4–6,40,41,47–51,68]. In that context, downstream marine impacts should not be viewed in isolation from upstream land management. They may also interact with wider ocean–atmosphere processes, including those associated with the sea surface microlayer, whose role in air–sea exchange, aerosol formation and pollutant enrichment may be more significant than has often been recognised [66–75].

# 20. Recommendations: Integrated Pollution and Flood Risk Management

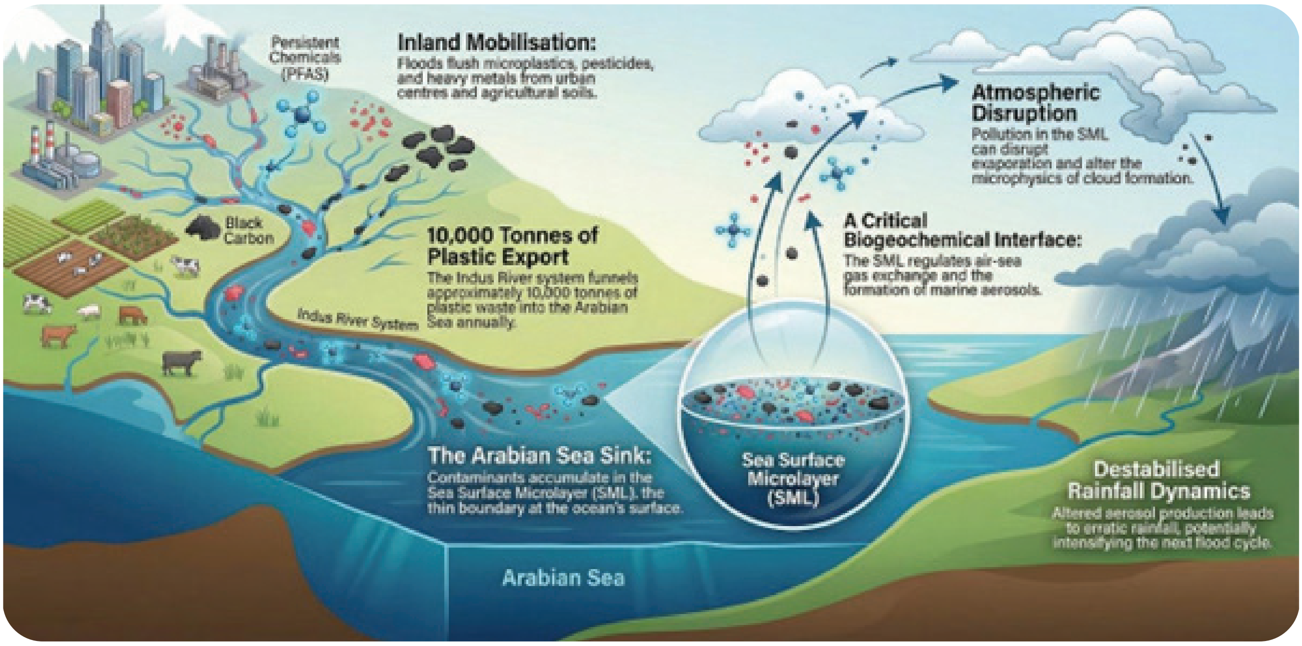
The evidence reviewed in this chapter indicates that several important drivers influencing flood intensity and pollution redistribution are at least partly amenable to national policy action.

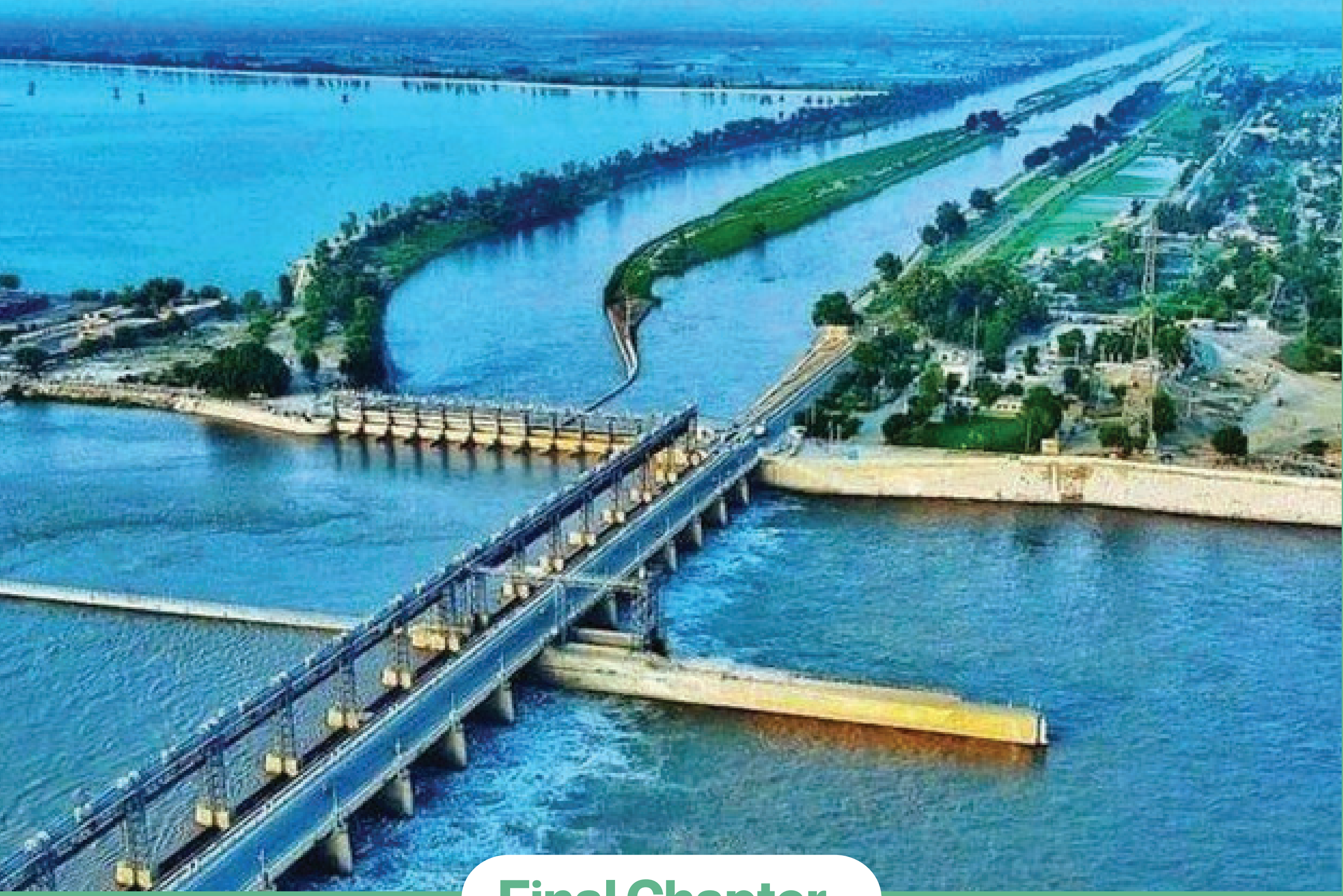
Measures such as reducing black carbon emissions, improving plastic waste management, limiting biomass burning, restoring forested catchments, strengthening stormwater management, improving wastewater and industrial pollution control, and protecting watershed infiltration capacity can reduce environmental contamination and flood risk simultaneously.

Clean air policies, pollution control, ecosystem restoration and flood risk management should therefore be addressed through integrated environmental governance, rather than treated in isolation. Because the scientific evidence demonstrates that atmospheric pollution, land degradation, cryosphere change and pollutant mobilisation are interlinked, joined-up action across these policy areas is likely to be more effective in building resilience and protecting ecosystems, lives and the economy.

For Pakistan, where major river systems discharge into the Arabian Sea, strengthening upstream pollution management also contributes to reducing pollutant loads entering marine ecosystems. This integrated approach offers multiple co-benefits, including improved public health, reduced flood damage, enhanced agricultural resilience and protection of downstream marine environments.

### Source-to-Sea: How Inland Pollution Disrupts Pakistan's Climate Cycle





Final Chapter

# INTEGRATED REFORM PATHWAY FOR PAKISTAN'S FLOOD RESILIENCE

## Integrated Reform Pathway for Pakistan's Flood Resilience

Pakistan's recurrent flood disasters are not the result of a single failure, and they cannot be solved through a single intervention. The preceding chapters show that flood risk in Pakistan is produced by the interaction of climate intensification, rigid river management, environmental degradation, fragmented institutions, poor land-use discipline, weak local preparedness, and repeated failure to embed lessons from past disasters into planning and practice. For that reason, incremental or fragmented interventions will not be enough. What is required is a coherent, integrated reform pathway that reduces exposure, strengthens resilience, improves coordination, restores natural protective systems, and embeds prevention into national planning.

The recommendations below therefore present an integrated reform pathway. They are grouped by theme but should be understood as mutually reinforcing. The aim is not merely to reduce flood losses in the next emergency, but to shift Pakistan from a reactive cycle of disaster and reconstruction toward a more preventive, adaptive, and resilient model of flood-risk governance.

### 1. Make flood resilience a core matter of national policy, economic planning, and security

Pakistan should formally recognise recurrent flood disasters, ecosystem degradation, and hydroclimate instability as issues of national economic security and long-term national resilience. Flood losses are now large enough to affect macroeconomic stability, public finance, food systems, infrastructure reliability, and social cohesion. The country should therefore treat flood-risk reduction not as a marginal environmental issue, but as a central component of national planning and state capacity.

This requires:

- integrating flood-risk reduction into national development and fiscal planning
- recognising ecosystems as part of the country's protective infrastructure
- aligning public investment priorities more closely with resilience needs
- ensuring that climate adaptation and disaster preparedness receive sustained policy attention rather than episodic attention after crises.

### 2. Integrate climate science into all major infrastructure and development decisions

A recurring failure identified throughout this report is the disconnect between climate knowledge and development planning. No major infrastructure or high-exposure development decision should proceed without mandatory climate-risk screening. Public investment can no longer rely on outdated hydrological assumptions or historical flood baselines alone. Planning must reflect the realities of intensifying rainfall, compound hazards, cryosphere instability, and the full range of flood and hydroclimatic risks facing Pakistan, including riverine, flash, urban, glacial, cloudburst-induced, and coastal flooding.

This should include:

- updating rainfall-intensity, runoff, storm-surge, and flood-frequency assumptions used in infrastructure design
- requiring compound-hazard assessment, including riverine, flash, urban, glacial lake outburst, cloud-burst-induced, and coastal flood risk
- integrating climate-risk screening into Planning Commission approvals and public investment appraisal
- reviewing existing infrastructure in known high-risk zones through a climate-risk lens
- upgrade urban drainage planning and protect natural drainage corridors in rapidly expanding settlements and cities

### 3. Reform floodplain governance and stop rebuilding risk

The report shows that floodplain encroachment and weak land-use discipline are among the clearest drivers of repeated flood disasters in Pakistan. Permanent construction in active floodplains continues, enforcement is inconsistent, and regulatory frameworks remain uneven across provinces. As a result, public and private resources are repeatedly used to rebuild risk rather than reduce it.

Pakistan should:

- establish stronger and more consistent floodplain regulation across provinces
- prohibit or severely restrict permanent construction in active flood zones
- strengthen enforcement against encroachment on riverbeds, floodways, and drainage corridors

- require flood-risk disclosure in development and land-use decisions
- avoid reconstruction in locations known to be repeatedly exposed unless resilient relocation or redesign is demonstrably not possible.

## 4. Shift from a flood-control paradigm to integrated flood management

A central theme across the report is that Pakistan's inherited model of trying to "fight floods" through embankments, levees, bunds, and channelisation has reached its limits. While structural protection remains necessary in some locations, indiscriminate dependence on river confinement can raise long-term risk by increasing sedimentation, elevating riverbeds, transferring pressure downstream, and locking settlements into dangerous positions.
Pakistan should progressively move toward integrated flood management by:

- using structural protection more selectively and strategically
- restoring wetlands and floodplain storage where feasible
- reconnecting rivers to designated overflow or retention zones
- prioritising ecosystem-based approaches alongside engineered solutions
- reviewing barrage operations, bund placement, and river training measures in the light of current and future hydrological realities

The objective should not be to abandon flood protection, but to combine it with approaches that reduce hydraulic stress and work with river systems more intelligently.

## 5. Modernise early warning systems and make warnings actionable

The report makes clear that early warning is not only a technical issue but also a governance and communication issue. Forecasting capacity has improved, but dissemination, accessibility, credibility, and response readiness remain uneven. Warning systems fail when data are delayed, communication is over-centralised, or local populations do not receive warnings in forms they can understand and act upon.
Pakistan should therefore:

- expand and modernise hydrometeorological monitoring networks
- improve real-time stream-gauge and weather-station data systems
- decentralise appropriate aspects of warning dissemination and response activation
- issue warnings in vernacular languages, not only English or Urdu
- link warning levels to clear action protocols understood by the public
- embed flood preparedness and warning literacy into schools and local awareness programmes

Warnings should be designed not simply to inform, but to trigger timely and proportionate action.

## 6. Institutionalise vulnerability profiling and socially informed preparedness

A recurring insight in the report is that vulnerability is not uniform. The ability to respond to flood warnings depends on income, gender, geography, mobility, livestock dependence, and access to communication and transport. Universal assumptions about evacuation capacity are often unrealistic, especially in rural and high-exposure areas.
Pakistan should develop systematic vulnerability profiling in hazard-prone areas, supported by:

- identifying highly vulnerable households and settlements
- recognising gendered barriers to warning access, evacuation, and relief
- planning for livestock and livelihood protection alongside human evacuation
- targeting shelters, evacuation support, and relief systems according to local realities
- integrating social vulnerability assessment into district-level preparedness planning
- design shelters and evacuation planning around rural realities, including livestock dependence and livelihood protection

Preparedness that ignores lived realities will continue to fail those most at risk.

## 7. Build community-based disaster risk management as a permanent national capability

The report supports the institutionalisation of community-based disaster risk management as a core pillar of national preparedness. . In many locations, especially mountainous districts, remote valleys, and isolated settlements, local communities are always the first responders. Yet local capacity remains uneven and often depends on short-term projects rather than permanent systems.

Pakistan should:

- establish or strengthen village- and community-level disaster committees in high-risk areas
- train local volunteers in evacuation, rescue, first aid, and communication
- pre-position basic rescue and emergency equipment at local level
- link local response systems more effectively with district and provincial disaster management authorities
- make CBDRM a routine part of preparedness rather than an exceptional donor-led activity

Resilience must be built where the hazard is first experienced.

## 8. Improve institutional coherence, expertise, and implementation discipline

The report does not argue that Pakistan lacks institutions. It argues that existing institutions are often fragmented, overlapping, poorly coordinated, and weakly aligned. Climate commitments are made nationally but not adequately integrated into provincial planning. Flood plans exist, but implementation remains partial and monitoring of compliance and preparedness is inconsistent.

Pakistan should therefore:

- improve coordination between federal and provincial flood-related institutions
- clarify responsibility for implementation, not just planning
- strengthen technical expertise in disaster management and flood governance
- ensure that flood plans, climate plans, and infrastructure strategies are aligned rather than parallel
- introduce stronger monitoring of whether preparedness and resilience measures are actually being implemented

Institutional proliferation without institutional coherence will not produce resilience.

## 9. Protect and restore ecosystems as part of national flood resilience

A major finding of this report is that ecosystems are part of Pakistan's flood protection system. Floodplains, wetlands, forests, upland catchments, mangroves, and drainage corridors all influence water retention, flood peaks, sediment movement, and ecological stability. Their degradation increases exposure and reduces resilience.

Pakistan should:

- restore wetlands in strategic flood-management zones
- reduce deforestation and strengthen catchment management
- protect natural drainage channels in urban and peri-urban areas
- recognise floodplains as hydrological assets rather than vacant land
- integrate ecosystem restoration into flood and water policy rather than treating it as a separate agenda
- review water-intensive cropping patterns and strengthen sustainable groundwater and catchment management in areas of rising hydrological stress
- Protect and restore ecosystems as part of national flood resilience
- align public spending, incentives, and land-use policy more closely with nature-positive investment and the reform of harmful incentives, consistent with CBD Target 18

This is not only an environmental agenda. It is a resilience agenda.

## 10. Address pollution, black carbon, and environmental risk amplifiers as part of flood resilience

The report shows that flood risk is amplified by pollution and environmental degradation. Black carbon accelerates cryosphere destabilisation. Land degradation and urbanisation increase runoff and peak discharge. Floodwaters also mobilise plastics, PFAS, particulates, sewage, and other contaminants across agricultural soils, river systems, and downstream marine environments, increasing risks to ecosystems, public health, and water-borne disease.

Pakistan should:

- integrate black carbon reduction into climate and flood-risk policy
- improve solid waste, wastewater, and industrial pollution control
- reduce biomass burning and other air-pollution sources that influence atmospheric processes and cryosphere stability
- strengthen catchment restoration and soil conservation
- treat flood management and pollution management as linked rather than separate policy domains

Joined-up action in these areas can generate multiple co-benefits for public health, including reduced contamination and disease risk, as well as for agriculture, ecosystems, and long-term resilience.

## 11. Strengthen post-disaster learning and implementation follow-through

One of the starkest conclusions of the report is that Pakistan repeatedly diagnoses its failures without fully correcting them. After each disaster, inquiries, assessments, and reform frameworks are produced. Yet the same weaknesses — poor land-use control, weak district preparedness, incomplete implementation of plans, insufficient climate integration, and reconstruction that restores rather than reduces risk — continue to reappear.
Pakistan should:

- treat post-disaster assessments as binding learning instruments, not advisory paperwork
- establish implementation tracking for key reforms recommended after major flood events
- require regular reporting on the status of preparedness and corrective action
- ensure that "build back better" principles are operationalised, not merely stated

The problem is no longer lack of diagnosis. It is a lack of sustained follow-through.

## 12. Expand international and transboundary cooperation to reduce risk

The report highlights the transboundary dimension of flood risk, especially in shared basins and upstream–downstream systems. Pakistan would benefit from more reliable hydrometeorological data-sharing, stronger technical cooperation, and better regional early-warning arrangements wherever feasible. The wider scientific and policy context also makes clear that climate change and geopolitical stress are increasingly converging around water security, while disaster is not inevitable where institutions, cooperation, and long-term planning are strengthened. At the same time, international climate finance remains insufficient relative to Pakistan's national needs.
Pakistan should:

- pursue practical technical cooperation for flood forecasting and hydrometeorological data exchange where possible
- strengthen its ability to access and utilise international adaptation and resilience finance
- improve project development capacity for resilience investment
- frame resilience not only as a domestic necessity, but as part of broader regional stability and long-term development

## Conclusion

The recommendations in this chapter do not constitute a single master plan. They amount to a necessary change in direction.
Pakistan must move:

- from response to prevention
- from fragmented mandates to coordinated governance
- from static assumptions to climate-informed planning
- from indiscriminate flood control to integrated flood management
- from top-down warning to actionable local preparedness
- from environmental neglect to ecological resilience
- from repeated learning failure to implementation discipline

Pakistan's flood challenge is severe, but it is not beyond remedy. The evidence assembled in this report shows that the country already possesses many of the lessons it needs. What is now required is to bring those lessons together into one coherent reform agenda and to act on them with urgency, consistency, and strategic seriousness.

Pakistan has reached a tipping point. What is now required is not incremental adjustment, but a full national reset in how flood risk, environmental resilience, and national security are understood, governed, and funded. Delay will not preserve the status quo; it will deepen the losses.


The Red Pathway to Flood Resilience: A Strategic Reset for Pakistan
US$80–85 BILLION IN CUMULATIVE LOSSES (2010–2025)
Flood damage at strategic parity with national defence spending. Breaking the 'Systemic Failure' Loop.
6. 'Room for the River' and Wetland Restoration: Give rivers space to meender, pruntise wetland and flood corridor restoration over universal embankment raising.
7. Institutionalise Community-Based Risk Management (CBRRM): Scale local preparedness to a permanent national capability, pre positioning reacue equipment at village level.
3. Strict Floodplain Governance: Probinit permanent construction in active flood zones: enfores land-use discipline to step rebuilding in high-risk areas.
9. Ecosystems as Protective Infrastructure: Recognise forests, mangroves & upland colchments as hydrological assets buffering against floods and regulating sediment.
Room for the River
Wetland Restoration
2. Mandatory Climate-Risk Screening for Infrastructure: Updated hydrological assumptions for all major projects reflecting intensifying rainfall & cryosphers metability.
8. Harmonise Institutional Coherence: End fragmentlation between federal federal & provincial bodies; clarity mandates and align climate commitments with lovel implementation.
10. Mitigate Pollution and Atmospheric Risk Amplifiers: Reduce black carbon emissions and biomess burning to slow glaster malt and prevent extreme rainfall intensification.
1. Elevate Resilience to National Security Status: Formally recognise flood risk & ecosystem degradation as core threats; incorporate into federal flecal planning.
2. Mandatory Climate-Risk Screening for Infrastructure: Updated hydrological assumptions for all major projects reflecting intencifying rainfall & cryosphere instability.
4. Transition to Integrated Flood Management (IFM): Use structural protection strategically; reconnect rivers to natural overflow zones & retention basins.
6. 'Room for the River' and Wetland Restoration: Give rivers space to meender, prioritise wetland and flood corridor restoration over universal embankment raising.
11. Accountability and Implementation Discipline: Treat post-disaster assessments as binding learning instruments with tracked implementation of reforms.
12. Strengthen Transboundary Cooperation: Pursue technical data-sharing & joint flood forccasting for shared basins, exparating ide-saving info-from geopolitical disputes.
Capital-heavy, post-disaster relief, restoring risk.
Risk-informed planning, ecosystem-based resilience, institutionalised lessons.
NotebookLM

# ENDNOTES

# References Chapter VI

## Pakistan's Recurrent Floods: Lessons Unlearned, Climate Realities, and the Imperative for Regional cooperation


1. National Disaster Management Authority Pakistan, Flood Situation Report, August 2025 (Islamabad: NDMA, 2025). Total casualty figures exceeded 1,000 by September 2025, with children comprising approximately 30% of fatalities. Primary causes of death included structural collapse, drowning, and landslides. Available at: https://www.ndma.gov.pk/

2. International Centre for Integrated Mountain Development (ICIMOD), Regional Cryosphere Monitoring Report: Hindu Kush Himalaya (Kathmandu: ICIMOD, 2024). The report documents the increasing diversity of flood types in South Asia, including the proliferation of GLOFs as a novel category of disaster risk linked directly to cryosphere warming. Available at: https://www.icimod.org/

3. World Weather Attribution, "Climate change intensified heavy monsoon rain in Pakistan, exacerbating urban floods that impacted highly exposed communities" (2025). The study employed multi-model ensemble analysis including 22 climate models from CMIP6, utilizing both observational data from Pakistan Meteorological Department stations and reanalysis datasets (ERA5). Available at: https://www.worldweatherattribution.org/

4. The 75% intensification figure for 2022 represents the increase in 60-day maximum precipitation attributable to anthropogenic warming above pre-industrial baseline. The 10-15% intensification for 2025 reflects that this event, while still intensified by climate change, occurred in a different meteorological context with more localized extreme rainfall patterns. See: World Weather Attribution (2025)

5. The hydrological connectivity between India and Pakistan operates through multiple pathways: (1) direct river flow from upstream Indian territories; (2) atmospheric moisture transport via monsoon systems; (3) pre-monsoon heatwave effects that alter soil moisture conditions in shared plains; and (4) glacial melt patterns in the shared HKH cryosphere. See: ICIMOD Regional Reports

6. The 30-50% damage reduction estimate derives from comparative analysis of transboundary river systems with functional early warning cooperation (Mekong, Rhine) versus those without such systems. Studies of the 2022 Pakistan floods suggest that 48-72 hour advance warnings could have enabled evacuation of vulnerable populations and protection of movable assets, potentially reducing economic losses by $5-8 billion. See: World Bank Pakistan Flood Reports

7. United Nations Office for the Coordination of Humanitarian Affairs, Pakistan Floods Emergency Response Plan (2010). The $10 billion economic loss figure represents direct damages and does not include long-term economic impacts such as reduced agricultural productivity, health costs, and educational disruption. Available at: https://reliefweb.int/report/pakistan/pakistan-floods-emergency-response-plan

8. The Lahore High Court tribunal report "A Rude Awakening" identified systematic failures in embankment maintenance, unauthorized construction in flood zones, and inadequate coordination between irrigation and disaster management authorities. The report's non-release by Punjab government raises questions about political accountability for identified negligence. See: Pakistan Judicial Records

9. Government of Pakistan, World Bank, Asian Development Bank, European Union, and United Nations, Pakistan Floods 2022: Post-Disaster Needs Assessment (October 2022). The assessment estimated damages at $14.9 billion and losses at $15.2 billion, with reconstruction needs of $16.3 billion for climate-resilient recovery. Available at: https://www.worldbank.org/en/news/press-release/2022/10/28/pakistan-flood-damages

10. The PDNA methodology involved sector-by-sector damage and loss assessment across 94 affected districts, incorporating inputs from federal and provincial governments, UN agencies, international financial institutions, and civil society organizations. The assessment followed international post-disaster assessment standards established by the Global Facility for Disaster Reduction and Recovery (GFDRR). See: GFDRR Standards

11. International Federation of Red Cross and Red Crescent Societies, "Pakistan floods: Escalating humanitarian crisis amid climate extremes" (2025). Casualty figures are subject to ongoing verification, but preliminary

reports indicate that structural collapse of inadequately constructed housing remained the leading cause of mortality, particularly affecting children and elderly populations. Available at: https://www.ifrc.org/press-release/pakistan-floods-escalating-humanitarian-crisis

12. Pakistan Planning Commission, Preliminary Assessment of Flood Damages (September 2025). The assessment's methodological limitations include the absence of standardized data collection protocols across provinces; lack of independent verification of reported damages; missing gender-disaggregated data; and no systematic district-level vulnerability mapping. Available at: https://www.pc.gov.pk/

13. World Weather Attribution (2025), op. cit. The study found that in the current climate (1.3°C warmer than pre-industrial), rainfall events of this magnitude now have a return period of approximately 5 years, compared to 15+ years in a pre-industrial climate. The intensification of 10-15% refers to the increase in total accumulated rainfall attributable to anthropogenic warming. Available at: https://www.worldweatherattribution.org/

14. The 2022 event demonstrated stronger attribution signals due to its exceptional spatial extent and temporal persistence. The 75% intensification figure represents the increase in 60-day basin-integrated precipitation that would not have occurred without anthropogenic climate forcing, based on multi-model attribution analysis. See: World Weather Attribution Studies

15. Pakistan Meteorological Department observational records (1961-2020) combined with IPCC AR6 regional projections for South Asia. The 3-6°C warming range reflects uncertainty in emissions scenarios and regional climate model resolution, with higher warming projected under SSP5-8.5 (high emissions) versus SSP2-4.5 (moderate emissions) pathways. See: IPCC AR6 Chapter 12 (Asia)

16. ICIMOD, op. cit. The HKH region contains approximately 54,000 glaciers and over 7,000 glacial lakes across Afghanistan, Pakistan, India, Nepal, China, Bhutan, and Myanmar. Pakistan's northern areas contain the highest concentration of potentially dangerous glacial lakes, with ICIMOD identifying 33 glacial lakes in Pakistan as posing high outburst risk. Available at: https://www.icimod.org/

17. Intergovernmental Panel on Climate Change (IPCC), AR6 Synthesis Report: Climate Change 2023 (Geneva: IPCC, 2023). Chapter 12 (Asia) provides region-specific projections showing high confidence in increased monsoon precipitation extremes and glacial melt acceleration under all emissions scenarios, with intensity scaling proportionally to global mean temperature increase. Available at: https://www.ipcc.ch/report/ar6/syr/

18. The 50% underestimation refers to the gap between observed increases in extreme precipitation intensity (approximately 22% increase in 30-day maximum rainfall over 1950-2020) versus the increase predicted by ensemble climate model means (approximately 12%). This suggests that either models are insufficiently sensitive to regional precipitation extremes or that observed changes include contributions from natural variability in addition to forced climate change. See: IPCC AR6 Technical Reports

19. David Jiménez, Children of the Monsoon: Life and Death Along the Ganges (New York: Rayo, 2008). Jiménez's journalistic account traces the monsoon's path across South Asia, documenting how environmental systems link the region's populations regardless of political borders. Book available through major retailers

20. The 2014 Kashmir floods demonstrated the predictable cascade pattern: heavy rainfall in Indian-controlled Kashmir (380mm in 24 hours in some areas) caused the Jhelum River to exceed danger levels by over 4 feet. The flood wave traveled downstream into Pakistani Punjab within 12-18 hours, with Pakistani authorities receiving only informal notifications rather than systematic early warnings through bilateral coordination mechanisms. See: Historical Flood Data

21. The March-April 2022 heatwave saw temperatures in northwest India and Pakistan reach 45-49°C, some 4-8°C above normal. This pre-monsoon heat accelerated snowmelt in the western Himalayas, increased soil evaporation, and created atmospheric conditions that contributed to the exceptional monsoon intensity that followed in July-August 2022. See: WMO Climate Reports

22. Cyclone Tauktae (May 2021) made landfall in Gujarat as an extremely severe cyclonic storm, causing extensive damage along India's west coast before its remnants brought heavy rainfall to Sindh and Balochistan. The storm demonstrated how Arabian Sea tropical systems, intensified by warming sea surface temperatures, affect both countries sequentially. See: WMO Tropical Cyclone Reports

23. The 30-50% damage reduction estimate is based on comparative analysis of flood impacts in basins with and without functional early warning systems. Studies of the 2004 Indian Ocean tsunami showed that early warning provided by natural indicators allowed communities in some areas to evacuate, reducing mortality by 60-80% compared to areas without warning. Similar principles apply to flood early warning, though lead times are typically shorter (24-72 hours for floods versus minutes for tsunamis). See: UNDRR Early Warning Reports

24. The Mekong River Commission (established 1995) operates the Mekong Flood Early Warning System, which provides flood forecasts up to 5 days in advance through a network of 25 telemetric stations sharing real-time data. The system continues to function despite periodic tensions among member states (Cambodia, Laos, Thailand, Vietnam), demonstrating that technical cooperation can be sustained through political changes. Available at: https://www.mrcmekong.org/

25. The International Commission for the Protection of the Rhine (ICPR) coordinates flood management across nine countries through the Rhine Alarm Model, which provides forecasts up to 48 hours in advance. The system operates through legally binding agreements that have remained in force since 1950 despite major political changes including German reunification and EU expansion. Available at: https://www.iksr.org/en/

26. The Arpacay (Arpaçay) Dam on the Akhuryan River, which forms part of the Armenia-Turkey border, continues to be jointly operated through monthly technical meetings despite the absence of diplomatic relations and the closed border. Water sharing is based on the 1927 Soviet-Turkish agreement, which allocated 50% of the river's flow to each country. Technical staff from both countries meet at the dam site to coordinate releases, conduct maintenance, and share hydrological data. See: Transboundary Water Cooperation Reports

27. The Indus Waters Treaty (1960), Article VII, establishes the Permanent Indus Commission with authority to address "any question" arising from the treaty, including matters of common interest related to water management. The Commission is required to meet regularly but has not been utilized to address climate adaptation challenges such as flood forecasting, extreme weather coordination, or glacial lake monitoring. Treaty text available at: https://www.worldbank.org/

28. Analysis of official meeting records shows that the Council of Common Interests met only 12 times during 2018-2023, well below the constitutional requirement for regular meetings. The Pakistan Water Council, established in 2018, held its first and only meeting in July 2018. The National Economic Council similarly met infrequently during this period. See: Government of Pakistan Records

29. National Flood Protection Plan-IV (NFPP-IV) was approved by the Council of Common Interests in May 2017 with an initial budget of PKR 800 billion (approximately $2.87 billion at 2017 exchange rates). The plan covered 10 years (2015-2025) and included structural measures (embankments, retention basins) and non-structural measures (early warning systems, land-use planning). Following the 2022 floods, the plan was revised in 2024 to incorporate climate adaptation measures. See: NDMA Planning Documents

30. Government of Pakistan, Ministry of Climate Change, National Climate Finance Strategy (2024). The $348 billion figure represents estimated adaptation needs across all sectors (water, agriculture, infrastructure, health, ecosystems) through 2030, based on sectoral vulnerability assessments and international climate finance assessment methodologies. Available at: https://mocc.gov.pk/

31. The Green Climate Fund (GCF) has approved $5.5 billion for adaptation projects globally since 2015, while the Adaptation Fund has mobilized $1 billion. Pakistan has accessed only a small fraction of available adaptation finance, with approved GCF projects totaling approximately $160 million as of 2024. This underutilization reflects institutional capacity constraints in project development and proposal preparation rather than lack of available finance. Available at: https://www.greenclimate.fund/

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## Flood Risk in Pakistan as a Compound Hydroclimate System: Pollution, Monsoon Dynamics and Watershed Processes

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# PANEL OF EXPERTS

**PAKISTAN AT THE FLOOD TIPPING POINT**

Systemic Risk, Climate Breakdown, And The Pathway To Resilience

## Ali Bin Shahid

Climate & Ecosystem Repair Architect

Ali Bin Shahid is a Climate and Ecosystem Repair Architect based in Islamabad. His methodology identifies geographic trigger points where hydrology, forest systems, and atmospheric dynamics are tightly coupled, then maps targeted interventions that redirect those dynamics toward recovery. He has applied this framework across active projects in Pakistan, Spain, Colombia, Jordan, Portugal, and California. He is the founder of PSKL Water for All and publishes the Regenesis series on water-cycle repair and atmospheric science, now past 215 episodes. His current work spans ecosystem restoration and land-atmosphere feedback analysis across Europe, Latin America, and South Asia.

## Dr Huma Sheikh

Senior Consultant Gynaecologist/
Women's Health & Climate Change

With more than 26 years of experience in clinical practice and medical education, Dr Huma is a senior consultant gynaecologist based in Gujranwala, Pakistan. Her expertise encompasses high-risk obstetrics, infertility, ovarian ageing, and maternal, child, sexual, and reproductive health. A dedicated advocate for sexual and reproductive health, she serves on the RCOG Advisory Board on Climate Change and Sustainability. In addition to her clinical leadership, she mentors MRCOG candidates and actively participates in global and national dialogues regarding the impact of climate change on women's health.


## Nawaz Haq

Founder, Revive Earth | Systems
Based Climate Solutions

Nawaz Haq is the Founder of Revive Earth, where he leverages an extensive entrepreneurial background to address complex environmental and climate issues. By employing a systems thinking methodology, he operates at the nexus of innovation, policy, and science to bridge disciplinary gaps and facilitate tangible outcomes. Nawaz provides strategic counsel to various businesses and NGOs and is an active participant in international climate dialogues. His core areas of expertise include clean energy infrastructure, biodiversity, ocean health, and the mitigation of air and wider pollution through the optimisation of existing transport and energy systems.

## Noreen Haider

Co-Founder, Revive Earth

Noreen Haider is the Co-Founder of Revive Earth. She is the Climate Editor for The Friday Times and is a seasoned social development professional with extensive expertise in disaster management policy and practice. A recognized authority in her field, she authored Pakistan's first Disaster Directory and is a certified Master Trainer in Climate Change mitigation and adaptation, Disaster Risk Reduction, and Disaster Risk Management. Her contributions to the sector extend to developing training resources and producing documentary films, as well as rendering trainings on disaster management and disaster reporting throughout Pakistan.

## Dr. Willem Van Deursen

Carthago Consultancy

An independent senior expert in strategic water management and integrated water resources, Dr. Van Deursen holds a PhD in Physical Geography. He possesses extensive experience in hydrological, participatory, and rapid assessment modeling across regional, urban, and rural contexts. Throughout his career, he has conducted professional work in several countries, including Pakistan, Vietnam, China, Bangladesh, and the Netherlands.

Currently, Dr. Van Deursen leads Carthago Consultancy in Rotterdam and serves as an advisor to the Sindh Irrigation Department.

## Dr. Danish Mustafa

Professor of Critical Geography,
King's College London

An expert in critical geographies, environmental hazards, and climate risk, Dr. Mustafa has made significant contributions to several influential publications, including The Politics of Water in South Asia and Ecologies of sustainable development goals: a mid-term perspective.

His professional impact includes co-authoring the inaugural climate change response strategies for Pakistan and serving as the lead author for the UNDP Pakistan Five-year Flood Strategy

## Ali Tauqueer Sheikh

Senior Consultant ADB

As Pakistan's leading expert on climate policy, sustainable development, and environmental strategy, Ali Sheikh, Tamgha-e-Imtiaz, holds a seat on the Prime Minister's Climate Change Council and represents the nation on the international board of the Loss and Damage Fund. He remains a central figure in shaping national policy, providing expert guidance on climate finance and the development of Carbon Market Guidelines as of early 2026. He is the principal author for both the 2021 Nationally Determined Contributions (NDCs) and the 2024 National Climate Finance Strategy for Pakistan.

## Dr. Muhammad Arfan

Climate Change and Water Management Specialist

Currently a climate change specialist at Blue Mont Inc. in Washington DC, Dr. Muhammad Arfan's expertise lies at the nexus of environmental studies and political sociology. His professional contributions involve a critique of conventional technical water management strategies within Pakistan. Previously, he served as a Research Fellow at the US Pakistan Center for Advanced Studies in Water, focusing specifically on integrated water resource management and groundwater modeling

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